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Technical efficiency of organic rice farming in Ngawi Regency (The case of the Komunitas Ngawi Organic Center)

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Abstract. Soil degradation fertility is a form of environmental damage due to climate change, ironically caused by the agricultural sector as the largest contributor to global warming. One of the efforts to overcome the problem of climate change issues in the agricultural sector is through organic rice farming practices. This study aims to analyze organic rice farming which includes farming profiles, influencing factors, and technical efficiency level of organic rice farming in Ngawi Regency which focuses on the Komunitas Ngawi Organic Center (KNOC). This study used a quantitative descriptive basic method with a census of all active member organic rice farmers of KNOC. The production factors of organic rice were analyzed using the Cobb-Douglass stochastic frontier production function. The results showed that in general the average organic rice farming profile on certified land was superior than non-certified land, with 1.96 R/C ratio on certified land, while 1.41 R/C ratio on non-certified land. The time it takes for land to become certified organic is three consecutive growing seasons applying supervised organic farming. Production factors that positively significantly influence organic rice farming are land area, labor, and organic pesticides. Excessive use of organic fertilizer input can increase the number of wild weeds on organic rice fields which can inhibit the growth of organic rice and reduce grain production. The level of technical efficiency achieved by respondent farmers varies widely between 0.57 - 0.93 with an average of 0.80 which is considered efficient.

1. Introduction

Degradation of soil fertility is one of the impacts of environmental damage caused by climate change. Directly, climate change has an impact on decreasing the content of organic carbon in the soil (SOC) which is the benchmark for soil health [1]. Ironically, the agricultural sector is one of the largest contributors to greenhouse gases (GHG) which causes global warming and climate change. The International Panel of Climate Change's research shows that crop agriculture, forestry and livestock contribute around 24% of the total factors causing climate change. Methane (CH4) and nitrous oxide (N_2O) emissions are the main contribution of the agricultural sector to global warming [2].

Apart from the problem of climate change, the agricultural sector also has the challenge of continuing to produce enough food production for the human population, which is estimated to reach 9 billion people by 2050. However, efforts to increase food production through conventional methods that do not pay attention to sustainability have worsened soil conditions and environment in the long term [3]. Agricultural mitigation efforts to overcome the problem of soil damage due to climate change while still producing sustainable food that is good for the environment and healthy for consumption that is through organic agriculture [4].

Organic farming has a good potential to reduce GHG emissions. Organic agriculture aims to increase fertility and nitrogen in the soil through stabilization of soil organic matter so that CO_2 absorption occurs in the soil [5]. A farm is said to fulfill organic principles if holistically both the input and the production process are environmentally friendly, so that it can produce products that are healthy and safe for consumption. Organic rice is an organic agricultural commodity that provides health value added because it does not contain chemical residues that harm the body, fluffier taste, and a relatively longer shelf life than non-organic rice [6].

Table 1. Area of organic land and organic rice land in Indonesia 2014 – 2018.

Year	Organic agriculture area (ha)	Organic rice area (ha)	Percentage (%)
2014	113,638	1,314	1.16
2015	130,384	1,364	1.05
2016	126,014	1,401	1.11
2017	208,042	53,826	25.87
2018	251,630	53,974	21.45

Source: [7].

Aliansi Organis Indonesia (AOI) said there was a significant increase in the area of organic rice in Indonesia from 1,401.32 ha in 2016 to 53,826 ha in 2017. The increase in the area of organic farming in Indonesia from 2014 to 2018 was also followed by an increase in the area of organic rice land. The data states that in 2018 organic rice land reached 21.45%, which is around 53,974 hectares of the total area of organic agricultural land in Indonesia of around 251,630 hectares (Table 1). The demand for organic rice has increased and this is proportional to the conversion of organic land to organic rice where there has been an increase in the area of organic rice. Organic rice is the second most purchased organic product by consumers after organic vegetables [8]. The potential of the organic market makes organic rice commodities one of the opportunities for sustainable farming which is carried out in various rice producing centers in Indonesia.

Table 2. Production, harvested area, and rice productivity in Ngawi Regency 2015 – 2019.

Year	Production (Ton)	Harvested Area (Ha)	Productivity (Ton/Ha)
2015	753,285	124,429	6.05
2016	818,985	133,836	6.12
2017	819,203	133,486	6.14
2018	842,221	132,776	6.34
2019	831,878	131,327	6.33

Source: [9].

Ngawi Regency is one of the central rice-producing areas in East Java. Rice production and productivity in Ngawi Regency based on Table 2 shows a fluctuating value from 2015-2019. The Ngawi Regency Government realizes that the impact of climate change can threaten food security as well as the potential for promising organic market potential, so this is in line with the high level of rice production in Ngawi Regency, the local government has the policy to develop organic rice farming [10]. The Ngawi Regency Government welcomed the presence of KNOC as a forum for organic farmer communities until it was legally established as a community institution in 2012. Komunitas Ngawi Organik Center (KNOC) as a farming community is actively involved in developing organic agriculture, especially organic rice commodities. KNOC exists because of restlessness about the damage to land resources due to climate change and conventional agricultural practices that are high in synthetic chemical inputs [11].

The problem that arises is the fear of the risks that will be experienced by farmers if they apply organic rice farming on land that previously applied conventional farming will experience a significant decrease in production. Analysis of farm costs and income is carried out in order to provide an overview of the feasibility of organic rice farming on certified organic land and on land during the conversion period. The production factors that need to be considered in increasing organic rice production are also analyzed. Although applying the same technology in organic rice farming, technically the level of efficiency of each farmer varies. Inefficient use of the amount of input will also reduce the level of farm technical efficiency which can lead to decreased revenue. So that it is necessary to analyze the level of technical efficiency of organic rice farming in Ngawi Regency as a consideration in the use of production inputs to increase technical efficiency. Through organic rice farming, farmers not only participate in reducing the impact of environmental damage due to climate change and economically can increase farm income [12].

2. Methods

The research was conducted in Ngawi Regency as a rice production center in East Java, with a purposive method with the case in an organic farming community, namely the Komunitas Ngawi Organik Center (KNOC), which is a reference for local organic farming. Determination of the sample using the census method to all active members of the KNOC, amounting to 40 respondents. Analysis of organic rice farming is divided into two categories that are organic rice farming on certified land and uncertified land through the calculation of farm revenue (R), farming costs (C), farm income (π), and R/C ratio [13].

The Cobb Douglas production function is used to determine the effect of land area, seed, manure, labor, and organic pesticides (local microorganisms) as the independent variable on organic rice production as the dependent variable. The estimation of the Cobb-Douglas stochastic frontier production function is analyzed using the Maximum Likelihood Estimation (MLE) method so that it becomes the following equation:

$$lnY = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + u_i \quad (1)$$

In this model, it consists of one dependent variable, that is organic rice production (Y) and five independent variables consisting of land area (X_1), seeds (X_2), organic fertilizer (X_3), labor (X_4), and organic pesticides / local microorganisms (X_5). In the frontier model with the MLE approach, the resulting output shows the gamma square value, which is the value of product variation produced by production efficiency.

The level of technical efficiency in organic rice farming is categorized into several groups called the technical efficiency index which describes the differences in the level of technical efficiency achieved by different organic rice farmers. The calculation of the technical efficiency (TE) of organic rice farming in Ngawi Regency is estimated by using the following mathematical equation:

$$TE_i = exp\,(-E\,[u_i \mid \varepsilon_i])\; i = 1,2,3, \ldots \text{n} \quad (2)$$

TE_i is the technical efficiency of the i-th farmer, which is $0 < TEi < 1$. The value of technical efficiency is only used for functions that have a certain amount of output and input (cross section data). The farm efficiency value is categorized as efficient if the value is ≥ 0.80 and is categorized as inefficient if the value is < 0.8. The value of technical efficiency is in the range of 0 to 1. If the technical efficiency of rice farming is 1 then the farming is technically efficient by 100%. A company is said to be technically efficient is a company that uses less input from other companies to produce a certain number of outputs or a company that can produce more output than other companies by using a certain number of inputs [14].

3. Results and discussion

3.1. Organic rice farming profile

Farming analysis in this study aims to see how the profile of organic rice farming in the Ngawi Regency, especially KNOC member farmers, as an organic community that contributes to efforts to deal with natural damage, one of which is climate change. How big the use of inputs (factors of production) greatly affects the production yield, business scale, and the level of farm efficiency [15]. The following table data on the average production yield and use of input factors for organic rice production.

Table 3. Results of production and use of organic rice farming production inputs.

Description	Unit of Measurement	Non-Certified Land		Certified Land	
		Average	Per Hectare	Average	Per Hectare
Production	Kg	2,140	4,597	2,296	6,518
Land area	m^2	4,655	10,000	3,522	10,000
Seed	Kg	23	49	16	47
Organic fertilizer	Kg	4,889	10,502	3,702	10,509
Labor	days working	139	298	114	323
Organic pesticides	Liter	748	1,606	566	1,607

Table 3 shows that the average organic rice production per hectare on certified land is higher, that is 6,518 kg/ha, compared to non-certified land which is only 4,597 kg/ha. This is because the land that is certified organic has been declared free of chemical residues and the function of the soil has been regenerated properly, so that it can produce high organic rice production because the land has been released from dependence on inorganic chemical inputs. Organic rice farming analysis was carried out by using the calculation of the value of each factor used. This analysis includes the calculation of organic rice farming based on the output produced on each non-certified land and certified organic land. In addition to the income analysis, an R/C ratio analysis is also carried out to determine the productivity of each rupiah invested to generate revenue. The following is a table of revenue, cost, and income data for organic rice farming per hectare in Ngawi Regency.

Based on the guidelines for organic certification institutions in Indonesia, it takes at least three supervised consecutive planting seasons to implement organic farming. After passing, the land will be declared free of synthetic chemical residues and is eligible to receive an organic certificate. Based on the analysis of the financing structure and income of organic rice farming in Table 4 on a scale of one-hectare land area, it shows that the profile of organic rice farming in Ngawi Regency. It can be seen that organic rice farming on certified land is relatively better with an R/C ratio of 1.96 with an income of IDR 15,923,637.78/ha, when compared to organic rice farming on non-certified land with an R/C ratio of 1.41 with an income of only IDR 6,723,430.46/ha. This is consistent with research [16] which shows that the income of organic rice farming in East Priangan is relatively higher with an income of IDR 18,513,819.08/ha with an R/C ratio of 2.67, when compared to semi-organic farming with an income of IDR 10,437,439.83/ha with R/C ratio 2.18. Here, the role of land resources is very important in agricultural production, because healthy soil functions are needed to obtain optimal production in environmentally friendly sustainable farming practices.

The results of the analysis of the financing of organic rice farming show that the average cost of both non-certified and certified land is the component of the cash cost of external labor is the largest. On non-certified land the percentage of cash costs for external labor was 40.52% of the total cost of around IDR

16,262,606.06/ha, while on land with certificate it was 37.43% of the total cost of IDR 16,666,851.93/ha. The high cost of labor is caused by the decreasing number of farm laborers, so the wages paid are also increasing. The labor cost component on certified land is greater than the labor cost on non-certified land, which is because the number of labors required is more on certified land, especially in maintenance activities such as weeding and controlling plant pests.

Table 4. Revenue, costs, and income of organic rice farming per hectare.

Description	Unit of Measurement	Non-Certified Land		Certified Land	
		Amount	% TC	Amount	% TC
Revenue (R)	IDR/ha	22,986,037.00		32,590,490.00	
Production (GKP)	kg/ha	4,597.00		6,518.00	
Contract Selling Price	IDR/ha	5,000.00		5,000.00	
Cash costs	IDR/ha	13,323,304.31	81.93	12,866,668.23	77.20
Seed	IDR/ha	302,575.00	1.86	292,560.00	1.76
Organic fertilizer	IDR/ha	3,152,640.00	19.39	3,150,645.00	18.90
Organic pesticides	IDR/ha	1,285,272.00	7.90	1,284,640.00	7.71
External labor	IDR/ha	6,590,225.56	40.52	6,239,001.00	37.43
Land tax	IDR/ha	44,990.07	0.28	35,982.81	0.22
Technology	IDR/ha	1,947,601.68	11.97	1,863,839.42	11.19
Non-cash costs	IDR/ha	2,939,301.75	18.07	3,800,183.70	22.80
Internal labor	IDR/ha	2,532,760.47	15.57	3,431,734.00	20.59
Depreciation	IDR/ha	406,541.28	2.50	368,449.70	2.21
Total Cost (TC)	IDR/ha	16,262,606.06	100.00	16,666,851.93	100.00
Income (π)	IDR/ha	6,723,430.46		15,923,637.78	
R/C ratio		1.41		1.96	

3.2. Organic rice production functions

The method for analyzing the interaction between production factors and output is using the translog stochastic frontier production function. Table 5 shows the sigma-square value which shows the distribution of the error term technical inefficiency (u_i), which is 0.1259, which value is greater than zero, which means that there is an effect of technical inefficiency in the production function model. Meanwhile, the gamma value of 0.7279 indicates that the error term caused by the technical inefficiency component (u_i) is 72.79% that means the difference between actual production and maximum production is more due to the effect of technical inefficiency, while the remaining 27.21% is caused by the random error / noise (v_i) variable from external effects. The results showed that the factor of land area, labor, and organic pesticide had a significant effect on the production of organic rice with a positive coefficient, while the factors of seeds and organic fertilizers showed a significant effect with a negative coefficient.

Table 5. Estimation results of the translog stochastic frontier organic rice production function.

Variable	Symbol	Coefficient	t-Statistic	Std. Error
Constanta	β_0	0.9095	0.5840	1.5573
Land area	lnX_1	0.5855	1.7972**	0.2145
Seed	lnX_2	-0.0584	-0.5742	0.1016
Organic fertilizer	lnX_3	-0.1944	-0.3772	0.5153
Labor	lnX_4	0.4428	1.3612*	0.3253
Organic pesticide	lnX_5	0.3452	1.5459*	0.6324
Sigma-square	σ^2	0.1259		
Gamma	γ	0.7279		

Description: **significant at $\alpha = 5\%$ t-table = 1.6909
*significant at $\alpha = 10\%$ t-table = 1.3069

Based on the data presented in Table 5, the regression coefficient used with the T-test shows that not all production factors positively significant affect organic rice production. There are several production factors in this study that show a significant effect on the 90% and 95% confidence levels on the total sample of 40 organic rice farmers in Ngawi Regency. The variable of land area is the most responsive variable which has a positive significant effect on organic rice production at the 5% real level, with a coefficient value of 0.5855. This figure means that if there is an additional 10% of land with the assumption that other inputs are fixed (ceteris paribus), then the production can be increased by 5.85%. This is in line with research conducted in Tasikmalaya, where the addition of the production factor of land area by 10% will result in an increase in organic rice production by 7.23% at a significant level of 5%. Land owned by farmers is usually still divided and scattered, not in a stretch system, so extra organic supervision is needed. On a large expanse of land, it will proportionally increase the production of organic rice. Meanwhile, on limited and scattered land, innovation technology and good management are needed to increase organic rice production [17].

For the seed variable, it is a variable with a negative effect on organic rice production with an elasticity coefficient of -0.0584, meaning that the addition of the number of seeds is 10% with the assumption that other inputs are constant, so it tends to reduce organic rice production. This is due to the lack of proper handling by farmers during the organic rice seedling process and the varying quality of the seeds received. In addition, there are still farmers who try to use seeds from the harvest in the previous season whose quality is not guaranteed. Quality seeds promise good production when accompanied by good agronomic treatment and balanced technological inputs. On the other hand, if the seeds used are not of good quality, the production is not promising or better than the use of quality seeds.

Another production factor that has a negative effect on organic rice production is organic fertilizers. The organic fertilizer variable has an elasticity coefficient of -0.1944, which means that if there is an addition of 10% organic fertilizer input with ceteris paribus conditions, it will tend to reduce organic rice production. This occurs due to the excessive use of organic fertilizer input on the land, resulting in a high increase in the growth of wild weeds. The disadvantage caused by wild weeds is the occurrence of competition with cultivated plants in extracting nutrients, water, sunlight and growing space. In addition, weeds can release *allelopathy* compounds which then become hosts for pests and pathogens of cultivated plants [18]. Efforts to mitigate climate change by increasing the input of organic fertilizers to land do not necessarily have a positive impact on the farmers' economy. Good and appropriate management of the use of organic fertilizers is needed so that the negative impact of excessive use of organic fertilizers can be reduced.

Production input with a positive significant effect that is responsive the second is labor with a regression coefficient value of 0.4428, which means that the addition of the number of workers by 10% in ceteris paribus conditions will increase organic rice production by 4.42%. The use of labor in this study combines labor within the internal family labor and the external family labor. The positive effect of the use of labor is due to the effective use of it to carry out intensive organic rice maintenance, especially in weeding activities to minimize wild weeds and control plant pests. The organic pesticide variable is a production input variable with a significant effect at the 5% level with a positive coefficient value of 0.345. This shows that if the input of organic pesticides in this case is liquid local microorganisms added by 10%, it will increase the production of organic rice by 3.45% in the ceteris paribus state. This positive effect is influenced by the function of organic pesticides which contain many local microorganisms for accelerating the decomposition process of organic matter and as plant pest control. The use of organic inputs that are rich in local microorganisms will maintain and improve the quality of soil fertility which is proven to be effective in mitigating climate change [19].

3.3. Technical efficiency of organic rice farming

Technical efficiency is one of the measuring instruments as an indicator to see farm performance. This research uses the concept of understanding technical efficiency with a certain input approach, namely how much production input can be changed to achieve a certain output. Organic rice farming is said to be technically efficient, if it can produce a certain number of outputs by using fewer inputs or it can produce a maximum number of outputs from the use of a certain number of inputs. The technical efficiency analysis in this study uses the stochastic frontier production function. A farm is said to be technically efficient if the technical efficiency index value is equal to or more than 0.80. The distribution of the technical efficiency values for organic rice farming can be seen in Table 6.

Table 6. Distribution of technical efficiency and potential production of the organic rice farming.

Technical Efficiency Distribution	Amount of Farmer	Avaerage TE (%)	Actual Procution (kg)	Potential Production (kg)	Potential loss (u_i) Production (kg)	Percent (%)	IDR (000)
0.51 – 0.60	2	58.75	2,585.00	4,400.00	1,815.00	70.21	9,075.00
0.61 – 0.70	3	67.97	1,083.33	1,593.92	510.59	47.13	2,552.92
0.71 – 0.80	12	77.91	1,956.67	2,511.50	554.83	28.36	2,774.15
0.81 – 0.90	19	84.54	2,223.68	2,630.43	406.75	18.29	2,033.73
0.91 – 1.00	4	92.18	3,642.50	3,951.72	309.22	8.49	1,546.11
Total	40						
Mean	0.80						
Minimum	0.57						
Maximum	0.93						

Based on Table 6, it shows the distribution of the varied efficiency indices of the respondent farmers. The results of the analysis show that most of the organic rice farmers, around 35 respondents, are technically efficient, while the remaining 5 farmers are technically inefficient. The level of technical efficiency achieved by respondent farmers varies widely between 0.57 at minimum until 0.93 at maximum with an average of 0.80 which is considered efficient. For farmers who achieve technical efficiency of 58.75% with actual production of 2,585.00 kg, in fact these farmers can achieve the highest production of 4,400.00 kg, so the farmers have lost their potential production of 1,815.00 kg. Meanwhile, in terms of economic value, farmers will lose potential revenue of IDR 9,075,000.00.

Based on Table 6 shows the respondent farmers of organic rice farming in Ngawi Regency, the average level of technical efficiency is not yet reach one or 100%. This shows that farmer respondents who are members of KNOC still have the opportunity to improve technical efficiency or actual production that is not yet reach potential production. The opportunity to increase organic rice production can be achieved by increasing skills and the ability to adopt more efficient organic rice cultivation technology innovations, increase in the performance of farm management, and considering the usage of environment friendly inputs as one of the solutions for the climate change issue [20].

4. Conclusions

Organic fertilizer is one of the agricultural production inputs that can regenerate soil fertility so that it can reduce the impact of global warming from the agricultural sector. However, excessive use of organic fertilizer input can increase the number of wild weeds on organic land which can inhibit the growth of organic rice and reduce grain production. Production factors that have a significant positive effect on organic rice farming are land area, labor, and organic pesticide. Comparatively, organic rice farming on certified land is superior to uncertified land, with an average income of IDR 15,923,637.78/ha and an R/C ratio of 1.96 on certified land, while IDR 6,723,430.46/ha and R/C ratio of 1.41 on uncertified land. The time required for land to obtain organic certification is three consecutive growing seasons in which organic farming is consistently applied and supervised. The level of technical efficiency achieved by respondent farmers varies widely between 0.57 at minimum until 0.93 at maximum with an average of 0.80 which is considered efficient.

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