Comparative analysis of technical efficiency between organic and non-organic rice farming in North Sumatera Indonesia

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Abstract. Non-organic farming will deteriorate the land and decrease the total factor productivity, which may result to higher production cost and low crop yield in the long run. However, Indonesian government initiative to become less dependent on non-organic rice farming by encouraging farmer to plant organic rice seems unsuccessful. Nevertheless, the most rice consumed in Indonesia is from non-organic farming. This study uses data envelopment analysis (DEA) based on non-parametric approach to measure technical, allocative and economic efficiency. This study found that pesticide and irrigation is underutilized, but fertilizer and labor are being overutilized. Even though most farmer are technically efficient, better efficient input allocation can improve the efficiency. Organic rice farming is less efficient than non-organic farming due to its low crop yield. Farmer with longer education background tend to be less efficient and more inclination toward planting organic rice.

1. Introduction
The majority of rice farmer in Indonesia are not using organic farming system. The organic farming system is considered impractical because of the low yield result compared to non-organic farming system. Arguably, most of the rice consumed in Indonesia is from non-organic farming system, agricultural practice with the use of chemical fertilizers and chemical pesticides [1]. However, the continuous use of chemical fertilizers and chemical pesticides has worsened the structure and composition of nutrients and soil fertility, which indirectly affects the land productivity [2]. The use of chemical fertilizer causes the soil depends on those substances to sustain the land productivity. In addition, [2] mention that the use of pesticides is also harmful for the environment because of its residual effects.

Non-organic rice farming system had depleted the land productivity in Indonesia, which is shown by a decline in factor productivity for non-organic wetland paddy [1]. It is a possibility that non-organic farming system might have a higher production cost and lower yield when farmers had applied it for every now and then on their land. The land deterioration causes farmer to use chemical substances in larger proportion to maintain high crop yield. Indonesian government
through “Go Organic 2010” had promoted organic agriculture with the intention of being a major marketer in organic crop market [1]. The use of organic farming system is expected to make farmer less dependent on chemical substances and maintain the land productivity in the long run.

Serdang Berdagai is one of the main districts in North Sumatera Province that plant paddy as a main crop. [3] mention that most of the rice farming are non-organic farming system, which lead to a question whether organic rice farming is less profitable and less efficient than non-organic rice farming. The farmer in Serdang Berdagai had applied the non-organic rice farming for sometimes, which should result in lower land productivity and high production cost.

The objectives of this study are; 1) to observe the efficiency on rice farming, 2) to analyze the the comparison of efficiency between organic and non-organic rice farming, 3) to observe the impact of farm characteristics and input use to efficiency.

2. Data and Methods

2.1 Data

Farm level data were collected from rice farmer in Serdang Berdagai District in 2017. The are 51 farm data comprises 20 organic rice farm and 31 non-organic rice farms. Five inputs were defined: seed, fertilizer, pesticide, labor and irrigation. As suggested by [4], this study assumes law of one price, because of the planting, harvest and selling agricultural product in the same district are in the same period. Farm characteristic data are collected to seek the correlation between operator and characteristic of the farm with overall level of efficiency. Farm characteristics are defined as: age, gender, farming type, experience, family member and education.

2.2 Methods

The data envelopment analysis is used to analyze the input-output efficiency comparison between organic and non-organic farming system. The comparison between those two-farming system will examine which production method is more efficient and provide explanation of cost minimization behavior.

Farrell explained that the efficiency of a decision-making unit (DMU) can be compared with another decision-making unit within a given group [5]. He proposed the measurement of efficiency by assuming a particular production function. There are three types of efficiency measures comprises technical efficiency (TE), allocative efficiency (AE) and Economic Efficiency (EE).

The relative efficiency can be measured not only by assuming a given production function, named as parametric approach, but also can be measured using data envelopment analysis (DEA) based non-parametric approach [6]. This study uses data envelopment analysis (DEA) based on non-parametric approach proposed by [7]. This study follows [8] and [9] for non-parametric analysis that will measure economic, allocative and technical efficiency with the assumption of cost minimization behavior of DMU. [8] stated that farmer behavior tends more to exhibit cost minimization behavior.

Technical efficiency (TE) measures the ability to produce a given level amount of output with the minimum input [5]. Consider the DEA for estimating technical efficiency using linear programming for DMUs at group J as follows:

\[ D^N(x_j^f, y_j^f) = \min \theta_j \]

\[ s.t \quad \sum_{j=1}^{N} \lambda_j x_{m,j}^l - \theta_j x_{m,j}^l \leq 0, \quad for \ m = 1, ..., M \]
Economic efficiency (EE) shows the minimum cost $C_j(w, y, T_c)$ of producing a given quantity of output ($y$), given input prices ($w$), and input ($x$) under constant return to scale technology. Consider the cost minimization DEA for measure economic efficiency by obtain cost minimization for DMUs at group $J$ using linear programming as follows:

$$\begin{align*}
\min_{x^*, \lambda^*} & \quad C_j(w, y, T_c) = \sum_{m=1}^{M} w^*_m x^*_m \\
\text{s.t.} & \quad \sum_{j=1}^{J} \lambda^*_j y^*_j - y^*_j \geq 0, \quad for \ m = 1, \ldots, M \\
& \quad \sum_{j=1}^{J} \lambda^*_j = 1 \\
& \quad \lambda^*_j \geq 0, \quad for \ j = 1, \ldots, N
\end{align*}$$

The economic efficiency is calculated as $EE_j = \frac{C_j(w, y, T_c)}{\sum_{m=1}^{M} w^*_m x^*_m}$

Allocative efficiency (AE) shows the minimum cost of producing a given level of output given input prices under variable return to scale technology [5]. Allocative efficiency (AE) is calculated using the technical efficiency and economic efficiency as follow:

$$AE_j = \frac{EE_j}{TE_j}$$

### 2.3 Tobit Model

This study will analyze the relationship between efficiency measures with farm characteristic using Tobit model. The latent dependent variables of the Tobit model are overall, technical and allocative, which are measured using non-parametric analysis. The Tobit model [10] was estimated as follows:

$$O_j = \sum_{i=1}^{T} C_i G_i + \varepsilon_i \quad \text{if} \quad \sum_{i=1}^{T} C_i G_i + \varepsilon_i < 1, \quad = 1 \quad \text{otherwise}$$

$O_j$ is the measure of efficiency (Pure Technical, Allocative and Economic Efficiency) for each farm, $C_i$ is an estimated parameter, and the explanatory variable ($G_i$)

The Tobit model will identify the factors related to inefficiency for different farming system. The explanatory variables used in Tobit model are the age, gender, farming type, experience, family member and the education level of farmer. Tobit model also used to analyze the relationship between efficiency and input use. The explanatory variables for input analysis are fertilizer, seed, pesticide, irrigation, and labor. The Tobit models will identify the importance of each input to efficiency analysis. The models also will show which inputs are being under-utilized or over-utilized. Thus, it will give suggestions to farmers of how to increase the efficiency of input use.
3. Result and Discussion

The average output of non-organic farming is more than a double of organic farming (see table 1). The average output for non-organic farming is Rp. 17,707,669 per hectare, in comparison with lower organic farming average output of Rp. 7,849,650. The price of organic rice is not significantly different than non-organic rice, at the other hand the yield is much higher for non-organic rice [3]. Unexpectedly, the cost of fertilizer is higher for organic farming because the use of costly natural fertilizer, fertilizer that made from the plant and animal.

The irrigation and pesticide cost are higher for non-organic farming. Non-organic farmer tends to apply more irrigation and pesticide to reduce risk in crop production. Risk averse farmer will significantly increase total water use for irrigation [11]. However, the most risk efficient irrigation for rice farm is the application of 1 cm height irrigation [12].

Farmer with organic farming have older age and longer period of farming experience (see table 1). On average, organic farmer are 7 years older and having 4 more years’ experience compared to non-organic farmer. Arguably, organic farmer has longer run objective in terms of land productivity compared to non-organic farmer that are more focused on short term output. In addition, farmer who apply organic farming is more educated than non-organic farmer.

Table 1. Summary statistic of output, input and farm characteristic use in DEA Analysis

| Variable          | Organic Farming, n=20 | Non-organic farming, n=31 |
|-------------------|-----------------------|---------------------------|
|                   | Mean                  | Std. Dev. | Min   | Max   | Mean                  | Std. Dev | Min   | Max   |
| Output/Output     |                       |           |       |       |                       |           |       |       |
| Output            | 7,849,650             | 7,975,035 | 1,720,000 | 33,600,000 | 17,707,669             | 15,607,486 | 4,050,000 | 86,775,000 |
| Seed              | 79,625                | 76,706    | 12,000 | 300,000 | 274,806              | 273,296   | 13,500 | 1,210,000 |
| Fertilizer        | 929,700               | 719,902   | 120,000 | 3,310,000 | 578,674              | 616,869   | 75,000 | 2,802,400 |
| Pesticide         | 147,000               | 208,125   | 0     | 875,000 | 561,516              | 1,501,244 | 75,000 | 8,609,000 |
| Irrigation        | 100,800               | 95,504    | 24,000 | 396,000 | 166,452              | 148,377   | 36,000 | 804,000 |
| Labor             | 1,952,713             | 1,797,614 | 427,500 | 7,455,000 | 3,269,516             | 3,337,165 | 645,000 | 18,085,000 |
| Farm Characteristic |          |           |       |       |                       |           |       |       |
| Age               | 55.4                  | 5.55      | 45.00  | 65.00  | 48.39                | 14.32     | 21.00 | 80.00 |
| Experience        | 20.95                 | 8.73      | 10.00  | 40.00  | 16.87                | 8.18      | 7.00  | 50.00 |
| Family Member     | 2.8                   | 0.60      | 2.00   | 4.00   | 2.32                 | 0.93      | 0.00  | 4.00  |
| Education         | 10.7                  | 3.51      | 6.00   | 16.00  | 8.74                 | 2.65      | 6.00  | 16.00 |

The DEA estimates of Technical, allocative and economic efficiency are summarized in Table 2. The technical efficiency measures show that most farmer are efficient. The technical efficiency score has an average of 88.4%, which implies it can be improved with the reduction of the input usage by 11.6% (i.e. if each farmer produced on the production frontier). Technical efficiency scores were higher than allocative efficiency; there are 10% of the farms has allocative efficiency measures smaller than 50%, while all technical efficiency scores are greater than 50%. The mean of allocative score is 79.5%, which suggests the rice farmer allocate inadequate input resources with a given input price by 20.5% higher than cost-minimizing level. The allocative efficiency has wide-ranging distribution from 37.3% to 100% that infers most farmers are less efficient. The
mean of economic efficiency score is 67%, which means the overall cost of rice production can be scaled down on average by 33% to achieve the same level of crop yield.

**Table 2.** The summary statistic of technical, allocative and economic efficiency scores

| Efficiency  | Technical | Allocative | Economic Efficiency |
|------------|-----------|------------|---------------------|
| <50%       | 5         | 12         |                     |
| 51%-75%    | 17        | 12         | 21                  |
| 76%-100%   | 34        | 34         | 18                  |
| Min        | 0.553     | 0.373      | 0.358               |
| Max        | 1         | 1          | 1                   |
| Average    | 0.844     | 0.795      | 0.67                |

The technical efficiency results suggest that it is more beneficial to drive the efficiency improvement through the increase of labor use. Using the efficiency score in table 3, it seems lower usage of pesticide and lower irrigation tend to be associated with the increase in technical efficiency. Furthermore, results in table 3 indicated that pesticide and irrigation is underutilized, but fertilizer and labor are being overutilized. With a given input price, the allocative efficiency can be increased if farmers enlarge the use of pesticide and apply higher rate of irrigation but reduce the usage of other inputs comprises labor and fertilizer. Irrigated farmers should focus on reducing fertilizer to increase economic efficiency.

**Table 3.** Tobit analysis for efficiency measures and farm inputs

| Input       | TE       | AE       | EE        |
|-------------|----------|----------|-----------|
| Seed        | -1.23E-08| -1.55E-07| -9.58E-08 |
| Fertilizer  | -7.89E-08| -2.14E-07*** | -1.98E-07*** |
| Pesticide   | -2.37E-07** | 1.94E-07* | 2.96E-08 |
| Irrigation  | -0.0000131** | 5.15E-06** | -4.49E-07 |
| Labor       | 7.32E-07** | -2.14E-07* | 7.81E-08 |
| _cons       | 0.9079   | 0.791    | 0.680     |

Result in table 4 suggest that a significant positive performance on allocative and economic efficiency comes from planting non-organic rice. Non-organic rice farmer has significantly higher crop yield which result in more efficient input allocation and producing on production frontier. The estimation results reveal a consistently significant positive relationship between longer experience with technical efficiency measures in estimated models. This could be farmer with longer experience adopting more efficient agricultural practices. The result show positive relationship between allocative efficiency and age of the farmer. Older farmer is more efficient in allocating input resources to achieve cost-minimizing level on producing a given crop yield.

**Table 4.** Tobit analysis for efficiency measures and farm characteristic

| Farm characteristic | TE      | AE       | EE       |
|---------------------|---------|----------|----------|
| Padi_Dummy          | -0.023  | -0.2416*** | -0.196*** |
We found a negative correlation between technical and economic efficiency with education. This finding is not surprising, because farmer with longer education background have more interest on planting less efficient organic rice. More educated farmer tends to have more awareness to maintain long term land factor productivity by applying sustainable agricultural practices, which considerably produce lower crop yield.

4. Conclusion

This study uses non-parametric analysis to examine the efficiency of organic and non-organic rice farming). The technical efficiency measures show that most farmer are efficient. Technical efficiency can be improved with the reduction of the input usage. The allocative score suggest that the rice farmer allocate inadequate input resources which result in producing higher than cost-minimizing level. With a given input price, the allocative efficiency can be increased if farmers increase the use of pesticide and apply higher rate of irrigation but reduce the use of labor and fertilizer. Irrigated farmers should focus on reducing fertilizer to increase economic efficiency. Older farmer is more efficient in allocating input resources to achieve cost-minimizing level on producing a given crop yield. Farmer with longer term of education tends to have more inclination toward planting organic rice.

5. References

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|       | Gender | Age     | Experience | Family Member | Education | _cons |
|-------|--------|---------|------------|---------------|-----------|-------|
| Value | 0.091  | -0.0298 | 0.056      | -0.029        | 0.056     | 1.022 |
| p-value | 0.00087 | 0.0031* | 0.0042     | 0.0031        | 0.0040    | 0.789 |
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