Technical Efficiency Of Upland and Downland Rice Farming In Border Area using MLE Frontier Production

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Abstract. The background research was Indonesian agriculture development towards food sovereignty. Rice is the main food crop everywhere in Indonesia including in the border area. The geographical constrains on the fulfillment of farming input and the position of the research location makes this research necessary. The technical efficiency of upland and downland rice farming was estimated using MLE frontier production. The result showed that the level of the obtained technical efficiency for upland and downland rice farming was varying between 23% - 99% and 88% - 99%, respectively. Moreover, it was found that the influencing factors of technical efficiency were farm size, seed, herbicide, and labor.

Keywords: efficiency, rice, border area, Frontier, MLE

1. Introduction
The future of development agriculture is aimed at realizing food sovereignty so that Indonesia as a nation can regulate and meet the food needs of its people in a sovereign manner. Food sovereignty is translated in the form of the nation's ability in terms of (1) meeting food needs from domestic production, (2) regulating food policies independently, and (3) protecting and prospering farmers as the main actors of the food agriculture business. Food sovereignty must start from food self-sufficiency, which is gradually followed by an increase in the value-added of agricultural businesses to increase the welfare of farmers[1]. The appointment of the North Penajam Passer Regency (PPU) as a candidate for the new capital city of Indonesia by the president on 26 August 2019 [2] certainly needs to be supported by additional food so that areas are needed as food buffers for the new capital city candidates. One of the areas that are being prepared to become a buffer for food barns is North Kalimantan Province. Apart from being a buffer for a food barn for prospective new capital cities, North Kalimantan Province which also had a border area was also being prepared as the development of an Export-Oriented Food Barn in the Border Region (LPBE-WP) as the embodiment of the concept towards Indonesia as the World Food Barn 2045.[3] The LPBE-WP concept refers to the idea of a World Food Granary 2045 (LPD-45) to provide food through increased production capacity, with the main characteristic of being in border areas and from the beginning its development was directed at developing food commodities that are also potential export commodities. Therefore, the types and competitiveness of food commodities being developed became the focus of LPBE-WP development in addition to its productivity aspects. Competitiveness can be realized through three approaches, they are, production efficiency, types of commodities selection, and the quality improvement through the
development of an intensive, even modern agricultural system, supported by downstream innovation. Exclusive food commodities that were unique and characterize local wisdom can be maintained, without neglecting the aspects of efficiency and productivity. However, one of the obstacles in realizing LPBE-WP is the scarcity of resources, including land, fertilizers, medicines, and labor. This problem can be solved, by increasing efficiency. Theoretically, efficiency can be achieved through two approaches. First, the efficiency of the use of inputs, in the sense that to produce a certain amount of product, the minimum input used was made. Second, with certain available inputs, efforts were made to produce the maximum possible output. Thus, increasing efficiency can also be viewed as an increase in productivity. From a production economic point of view, efforts to increase efficiency through these two methods are known as technical efficiency improvements.

Rice is the main food crop in Indonesia’s because most of Indonesia's population consider rice as a staple food source. However, the increasing rice production that Indonesia has, was not proportional to the increase of Indonesia rice consumption which forces Indonesia to import rice from other countries. A total of approximately two million tons of rice were imported in 2001, which immediately turned Indonesia into the largest rice importer in the world [4]. Therefore efforts to increase rice production through increasing rice productivity and farmers' income were always included in the government policy agenda in agriculture. [5] According to the Ministry of Agriculture [3] several studies in Indonesia showed that the level of technical efficiency of rice farming on average 0.76 with a range of 0.31-0.97. This indicates that efforts to improve technical efficiency are still quite open. Based on the land map from BPN in 2012, there were potential land areas in 13 districts covering 3.74 million ha for rice, corn, soybeans, shallots and, chilies, including 120 thousand ha for the development of sugar cane in Merauke and Malacca. The land consists of 645 thousand ha for the intensification and 3.10 million ha for the expansion of the planted area, both around existing land and in other areas. Of the 13 regencies, two were in North Kalimantan, there were Malinau Regency and Nunukan Regency.

Self-sufficiency RASDA (Regional Rice) is one of the Government programs in Malinau District to meet the food needs of the people in Malinau District and the program is expected to be able to meet other regions need as well. RASDA is expected to be applied in Malinau by considering the condition of the region that has enough potential and considerable regional support also, the majority of the population has already traditionally worked in the agriculture sector which is the main supporting factor in the Malinau District Government program to develop this program. RASDA is also very helpful in increasing food sovereignty and security in border areas which are far from food access from other regions. Increased production is expected to meet the needs of rice at the research site.

According to the data, rice production in North Kalimantan in 2019 was 33.36 tons. This number is still far below the national average of 54.60 tons [6]. Moreover, field rice generally has a planting period of six months which is why efforts to increase efficiency is still very much needed considering that six-month time constrain that field rice has. The purpose of this study was to determine the technical efficiency and the use of factors that influence the technical efficiency upland and downland rice farming in the border area of North Kalimantan by using the Stochastic Frontier approach.

2. Methods
This research was conducted in Pujungan Village, Pujungan District, and Semengaris Village, North Malinau District, Malinau Regency. Pujungan Village is a village located in the border area between Kalimantan and Malaysia. Due to themountainous conditions of the area in the village of Pujungan[7], rice cultivation in the area is carried out in the fields with a harvest period of once a year or a minimum planting period of 120 days until 180 days per planting season. Meanwhile, Semengaris is included in a village located in the lowlands so that many people work on downland rice farming. Rice cultivation in the area is the same like in Pujungan Village. Both Pujungan Village and Semengaris Village are predominantly Dayak people. The cultivation of upland rice farming in
Pujungan Village and downland rice farming in Semengaris Village is still very traditional without the help of more advanced technological help.

This research used qualitative and quantitative approaches. The qualitative description was used to describe upland and downland rice farming. Meanwhile, the quantitative approach was used to measure the level of efficiency of farmers in the use of production factors in the upland and downland rice farming. The method of determining the sample was done by taking all existing populations or by the census. The number of farmers in Pujungan Village was 72 people and 60 farmers in Semengaris Village.

Analysis of the data used to determine the efficiency level was through the Stochastic Frontier approach model by estimating The Maximum Likelihood Estimation (MLE). The analytical tool used was Frontier 4.1. As stated by [8],[9]. The function of the stochastic frontier equation was to calculate the level of efficiency in the upland and downland rice farming. The result was as follows:

\[ \ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \psi - \mu_i \]  

Where \( \ln Y \) was production, \( \beta_0 \) was intercepting, \( \beta_1, \beta_2, \beta_3, \beta_4 \) represent the estimator parameters, \( \ln X_1 \) was farm size, \( \ln X_2 \) was seed, \( \ln X_3 \) was herbicide, \( \ln X_4 \) was labor, and \( \psi - \mu_i \) was error term (inefficiency effect in the model). The major advantage of this method was that it provided numerical measures of technical efficiency. The technical efficiency of an individual farmer was defined in terms of the ratio of the observed output to the corresponding frontier output, given the available technology.

In summary, the research method can be seen in the figure 1:

**Figure 1. Flow Chart of Research Procedure.**

3. Results and discussion

3.1 Upland rice farming and Downland rice farming

The geographical location of upland rice farming research had no coastline. Therefore, all villages in the study location were non-coastal villages. The research location was directly adjacent to Bahau Hulu District and Malinau Selatan Hulu to the north, Bulungan Regency to the east, Kayan Hilir District to the south, and Negara Malaysia Timur-Sarawak to the west. Most of the people in the research location work as farmers of rice to earn a living for their family, the farmer's side job outside their farming activities mostly were hunting and looking for forest products (agarwood) for sale. Tradition or practice in cultivating upland rice or shifting cultivation systems has been a tradition of
the Dayak tribe for a long time due to the environmental factors in the upland and hilly highlands that make farmers have to farm in a nomadic way. Whereas, the location of the downland research was the expansion of the village of LubakManis. Most of the people work as rice farmers because the village's topography is mostly lowland.

![Research Area Map](image)

**Figure 2.** Research Area Map.

3.2. Production Factors of upland and downland rice farming

The use of production factors in the field of upland and downland rice farming consists of inputs in the form of land area, seeds, herbicides, and labor. For rice farmers, seed fields are referred to as banie. The seeds used were local seeds produced by farmers themselves. Seeds were produced from previous harvests. Quality of the seeds according to respondent farmers were seeds whose grain was dense-glossy, and had no insect bites or pest marks. Seeds candidates that have been harvested were dried in the sun for several hours and then stored in cans called beliek. The seeds than stored for more or less 7 months. Meanwhile, the seeds used by downland rice farmers were local varieties that have been passed down for generations. The use of herbicides in the field of upland and downland rice farming was intended to eliminate weeds in the field before planting rice. The use of labor both in the field upland and downland rice farming was from the family workforce working together to do all the work including starting for land management, planting, and harvesting. This has always been a tradition passed down by the Dayak tribe when carrying out its agricultural business activities. The used of production inputs in the business of upland and downland rice farming in the research location is shown in the table 1.

| No. | Input  | unit   | total  |       |       | unit   | total  |
|-----|--------|--------|--------|-------|-------|--------|--------|
| 1.  | seed   | kg     | 21,93  | seed  | kg     | 17,13  |
| 2.  | herbicide | liter  | 2,59   | herbicide | liter  | 1,07   |
| 3.  | labor  | HOK    | 13,89  | labor  | HOK    | 40,66  |
| 4.  | production | kg     | 1,089,84 | production | kg     | 1,055,56 |

3.3. Estimation Results of the Stochastic Frontier Production Function

The results of the analysis of the Stochastic Frontier production function can be seen in the table 2:
### Table 2. Estimation Results of the stochastic frontier production function MLE method

| Variable input       | Upland rice farming | Downland rice farming |
|----------------------|---------------------|-----------------------|
|                      | Coefficient         | standard Error        | t-ratio   | Coefficient         | standard Error | t-ratio |
| Constant             | 4.290               | 0.633                 | 6.778     | Constant            | 4.1407        | 0.4469  | 9.264   |
| Farm size            | 0.509*              | 0.064                 | 7.916     | Farm size           | -0.028        | 0.965   | -0.288  |
| Seed                 | 0.759*              | 0.058                 | 13.071    | Seed                | 1.1480*       | 0.074   | 15.553  |
| Herbicide            | 0.225*              | 0.086                 | 2.601     | Herbicide           | -0.185        | 0.0799  | -2.315  |
| Labor                | 0.123**             | 0.056                 | 2.193     | Labor               | -0.116        | 0.0973  | -1.914  |
| Sigma-square (σ²)    | 0.098               | 0.012                 | 8.135     | 0.0159              | 0.008         | 2.0124  |
| Gamma (γ)            | 0.999               | 0.911E-03             | 1097      | 0.348               | 0.409         | 0.850   |
| L-R test             | 11.664              |                       |           |                     |               | 1.5467  |
| Log LF MLE           | -1.636              |                       |           |                     |               | 48.783  |
| Log LF OLS           | -12.200             |                       |           |                     |               | 48.009  |
| CTRS                 | 1.616               |                       |           |                     |               | 0.819   |

#### 3.4. Analysis of Upland Rice Farming Production Function using The MLE method

The MLE method was considered as a very fitting model because it fulfilled the Cobb-Douglas assumption with log-likelihood of −1.636 which has a better value compared to the OLS method with −12.200 as stated in [7] and [10]. Sigma squared (σ²) = 0.098 is statistically significant at the level of α = 1 percent indicating that the production variation contributed by technical inefficiency (ui) is 9.8 percent. Inefficiency that happen in this case, came from the farmers internal factors such as age, education, number of family dependents, etc.). Value (γ) is a contribution of technical efficiency in the total residual effect. The gamma value obtained is 0.99. The number was very close to 1, indicating that the error term only comes from inefficiency (ui) originating from the farmers themselves as managers in farming and not from stochastic effects outside the model. The CTRS value obtained was 1.616, which indicated the scale of farming or elasticity of upland rice farming. This value was obtained from the sum of regression coefficients in the farm rice production function model, which means that if all production inputs are increased by 10 percent, production will also increase by 16.16 percent. The variable is positive and real value. Variable area of farm size, seeds, and herbicides have a significant effect with a significance level of α 1% while the variable use of labor α 5%. Land area can affect technical efficiency because the land area will determine the productivity of farming.

Superior seeds and appropriate treatment will affect the technical efficiency of farming, farmers in the research locations generally still use the seeds from the previous harvest and, the treatment of seeds before sowing is still very traditional, this will affect the output. Meanwhile, for herbicides in the research location, farmers use it at the beginning of land clearing, because using land herbicides to plant rice can be prepared more quickly, especially with a tugal system (without tillage). Land area and seeds affect technical efficiency.

#### 3.5. Analysis of Downland Rice Farming Production Function using The MLE method

The MLE method was considered as a model fit as it fulfilled the Cobb-Douglas assumption. MLE method value (48,783) was compared to OLS method (48,009) and the number showed that MLE method is better and more applicable to the real-life situation in the field. Sigma squared (σ²) = 0.0159 was statistically significant at α = 1 percent which indicated that the variation in production contributed by technical inefficiency (ui) 1.59 percent. The inefficiency in this case came from the
farmer’s own internal factors such as age, education, number of family dependents, etc.). Value (γ) was a contribution of technical efficiency in the total residual effect. The gamma value obtained as 0.348, indicating that the error term of 0.348 originates from inefficiency (ui) originating from farmers themselves as managers in farming and not from stochastic effects outside the model.

The condition of the scale of farming or elasticity of upland rice farming was shown by the CTRS value. CTRS obtained from the sum of the regression coefficients in the rice field farm production function model is 0.819 which means that if all production inputs are increased by 10 percent then production would also increase by 8.19 percent. Estimation of the production function by the MLE method in wetland rice farming, only seed variables have a significant effect with a significance level of α 1%. Seed variables affect the production of wet rice both organically and conventionally processed [11].

Distribution of Technical Efficiency Level in upland and downland rice farming in the research area can be seen in Table 3.

Table 3. Distribution of Technical Efficiency Levels for Upland and Downland Rice Farming.

| Technical Efficiency Levels | Upland Rice Farming | Downland Rice Farming |
|-----------------------------|----------------------|------------------------|
|                             | Farmers | Percentages | Farmers | Percentages |
| people                      | %       | people     | %       |
| < 0.30                      | 2       | 2.78       | 0       | 0           |
| 0.31-0.40                   | 3       | 4.17       | 0       | 0           |
| 0.41-0.50                   | 22      | 30.56      | 0       | 0           |
| 0.51-0.60                   | 16      | 22.22      | 0       | 0           |
| 0.61-0.70                   | 12      | 16.67      | 0       | 0           |
| 0.71-0.80                   | 5       | 6.94       | 0       | 0           |
| 0.81-0.90                   | 7       | 9.72       | 1       | 1.607       |
| 0.91-1.00                   | 5       | 6.94       | 59      | 98.33       |
| Total                       | 72      | 100.00     | 60      |             |
| Maximum                     | 0.99    |             | 0.99    |             |
| Minimum                     | 0.23    |             | 0.88    |             |
| Average                     | 0.59    |             | 0.97    |             |

From 72 respondent farmers, the average level of efficiency achieved was 0.59. This showed that the level of efficiency of upland rice farming was still not efficient because the average level of production efficiency as less than 0.7 (ET ≥ 0.7). Refers to [12] that a farming business is said to be efficient if its efficiency as greater or equal to 0.70. However, as many as 76.4 percent of that acted as respondent in this research was not yet technically efficient. The highest level of efficiency was 0.99 and the lowest (minimum) is 0.23. Inefficiency in production was caused by internal factors from farmers as managers. It can be seen from the results of the estimation of the frontier production function that the variation in production contributed by technical inefficiency (ui) is 9.8 percent. Inefficiency in this case came from the internal factors of farmers. The value (γ) was close to 1 which was 0.99, indicating that the error term only came from the inefficiency (ui) originating from the farmers themselves as managers in farming and not from stochastic effects outside the model. In contrast to the level of technical efficiency of downland rice farming, the level of technical efficiency of 60 rice farmers from an average level of technical efficiency reached 0.97. This showed the level of technical efficiency of rice farming has been efficient.

4. Conclusion
Based on the results and discussion it can be concluded that the level of efficiency of upland rice farming was still inefficient with an average value of 0.59 or 59%. Meanwhile, downlandrice
farming was technically more efficient with an average level of efficiency of 0.97 or 97%. The factors that influenced the efficiency of the technique of upland rice farming were the farm size, seeds, herbicides, and labor. Meanwhile for downland rice farming, the influencing factor was the seeds.

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