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Technical Efficiency Analysis of Rice Farming (Case Study)

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Abstrak: Efficiency is an important aspect for farmers as a tool for measuring production decisions regarding available alternatives. There are several differences in efficiency at the operational level, one of which is worth paying attention to is technical efficiency. The aims of this research are, to describe rice farming in Jati Village, Gondang Bojonegoro District, to analyze the technical efficiency of production in rice farming activities in Jari Village, Gondang Bojonegoro District, to analyze the influence of factors on technical efficiency in activities farming in Jari Village, Gondang District, Bojonegoro. The approach used to analyze the data is Data Envelopment Analysis (DEA) and Tobit regression. In the 2023 planting season, farmers are generally worried about climatic factors that are starting to be unpredictable, an uncertain climate will be an obstacle for farmers to plant rice twice, farmers are still not using inputs according to the recommended use, as in use of seeds and fertilizer. Farmers can still reduce seeds by 5.84 kg, fertilizer by 60.01 kg, plant maintenance medicine by 0.40 liters, labor by 3.81 HOK, and use of tractor engines by 94 minutes. Increasing technical efficiency in farming is strongly influenced by socio-economic factors of farmers. The factors that influence the technical efficiency value of rice farming in Jari Village are age and workforce. Efforts to increase rice farming can be done by using production inputs in accordance with the recommended composition of government programs.

Keywords: DEA; Technical efficiency; Tobit regression; Rice

Introduction

Indonesia is known as an agricultural country, because the majority of its population depends on the agricultural sector for their living. (Schoneveld et al., 2019); (Murphy et al., 2021), Agriculture is one of the main sectors in the Indonesian economy, with a large amount of agricultural land and a diversity of agricultural products such as rice, coffee, palm oil, and many others. Rice is a strategic food commodity to continue to be developed in Indonesia. This is because rice is still the main food ingredient that dominates the diet of Indonesian people. As a staple ingredient, rice is still the main choice compared to other food ingredients such as corn, sweet potatoes, sago and other ingredients (Dewayani et al., 2022); (Sumarwati, 2022). Rice is one of the strategic commodities whose demand increases as the population increases, (Ruspayandi et al., 2022); (Utami et al., 2023). Efforts to increase rice production in order to meet rice needs continue to be carried out in the hope of achieving sustainable rice self-sufficiency.

Indonesia has a strategic climate for developing agriculture. Indonesia's tropical climate supports the sustainability of agricultural activities. Various types of plants can grow well because the tropical climate means that Indonesia only has two seasons, namely the dry season and the rainy season. Jari Village is a village where the majority of the population are farmers. During the rainy season, farmers in Jari Village plant rice, shallots and corn. However, the majority of crops planted by farmers during the rainy season are rice, because rice is a plant that depends on water, during the dry season farmers in Finger Village plant corn and shallots. In previous years, rice farmers in Jari Village planted rice twice in one season, but recent climate changes which have become increasingly uncertain have

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created obstacles for rice farmers in Jari Village, where Jari Village is a rain-fed village without drainage. irrigation such as reservoirs or dams, agriculture in the village only depends on rainwater. This is an obstacle for farmers to produce more rice. Forecast data on the nature of rainfall in Gondang District, Bojonegoro Regency can be seen in Figure 1.

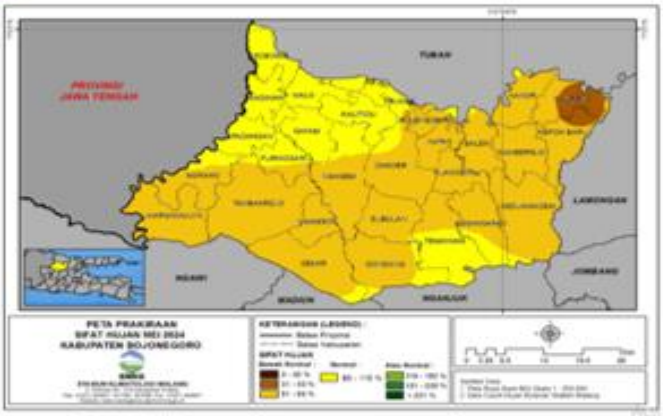

Figure 1. Forecast Data on Rainfall Characteristics for Gondang District, Bojonegoro Regency

It can be seen from Figure 1 that the rainfall level in Gondang District has a rainfall level of 31-50%, which is below the normal rate of 85-115%. Abnormal rainfall makes it difficult for farmers to decide how many times to plant rice on their activity that utilizes production factors in the form of land area, labor and capital. These activities are carried out agricultural land. Apart from uncertain climate changes, agriculture in Jari Village is also still not appropriate in the use of seeds and fertilizer for each area of land they cultivate according to recommendations from the Department of Agriculture. In one hectare of rice planting area, the recommended seeds are 25 kg with 500 kg of fertilizer. However, farmers are still unable to change their planting methods according to the guidelines for Continuous Fertilization Patterns. According to (Michelson et al., 2023); (Bakri et al., 2021), the use of inputs that are not in accordance with recommendations can be seen in the average use of production inputs from respondent farmers such as seeds, urea fertilizer and NPK fertilizer.

The use of inputs as recommended by extension workers is 20 kg/hectare, fertilizer 200 kg/hectare, this will trigger agricultural inefficiency. Jari Village, Gondang District, has a population whose majority work as farmers. The government in Jari Village has an agricultural institution or what can be called the Association of Farmer Groups (GAPOKTAN) to facilitate agricultural activities from the capital sector to agricultural products. According to ministerialregulationNumber:67/PERMENTAN/sm.050/12/2016, Farmer Groups (Poktan) are groups of farmers/breeders/planters formed by farmers on the basis of similar interests, similar social, economic and resource environmental conditions, and similar commodities, and familiarity to improve and develop members' businesses. The function of Poktan is to make it easier for farmers to improve their knowledge, skills and attitudes so that they can grow and develop into independent farming businesses through the use of and access to information sources and technology so that they can increase productivity, income and a better life.

Demand for rice continues to increase in line with demand for final consumption by households, non-household demand (processing industry and hotel restaurants) and the high rate of population growth. The climate is becoming more extreme due to global warming, which will have an impact on disrupting the rice production process. Rice production data in Gondang District, Bojonegoro Regency can be seen in Table 1.

Table 1. Rice Production in Gondang District based on Agricultural Land Area.

Year	Land Area (Ha)	Production (Kg)
2020	1316	14567.66
2021	1316	11304.93
2022	1316	9952.80
2023	1316	9840.63

Data obtained from the Bojonegoro Regency Food Security Service shows that rice production in Gondang District has experienced an insignificant decline. In 2020 and 2022 it experienced a decline and began to increase again in 2022 and 2023. In 2020 and 2021 were the first years of the arrival of Covid-19, there by reducing production patterns in the Gondang area, this will probably happen in various rice center areas in Indonesia. Apart from being influenced by the Covid-19 pandemic, this decline can also be influenced by several factors such as farmers' lack of ability to use agricultural technology, reduction in agricultural land, and the uncertain impact of climate change. According to (Zhang et al., 2021); (Pawlak & Kołodziejczak, 2020), farming is an with the aim of getting maximum results both in terms of profits and output produced.

Efficiency can be measured using stochastic frontier analysis (SFA) and data envelopment analysis (DEA) Vu Hoang Linh, (2012). Several previous studies were found to measure the technical efficiency of rice in Indonesia using the DEA model. (Cahyaningsih et al., 2022), stated that the DEA model was used to measure the technical efficiency of rice in Riau. This study has no efficient value (Mohammadpour et al., 2020); (Guo et al., 2020), suggest using Tobit regression to find out sources of inefficiency. Higher technical efficiency in input use reflects the ability of one input package used in rice farming to produce higher production compared to farming conditions with lower technical efficiency T Syaiful et al, (2019). So, the technical efficiency of using inputs encourages the usability or effectiveness of these inputs in producing higher production.

Due to the various obstacles in lowland rice farming, it is necessary to carry out more efficient rice farming through the application of various technologies. Efficiency is a comparison of output and input used in a production unit (Sgroi & Sciancalepore, 2022); (Giller et al., 2021), Efficient agricultural production will reduce production costs incurred by farmers. According to (Brockway et al., 2021); (Petropoulos et al., 2022), one indicator of efficiency is if a certain amount of output can be produced using a smaller number of combinations of inputs and with certain combinations of inputs it can minimize production costs without reducing output. produced by (Nuruzzaman, 2015); (Farida & Setiawan, 2022); (Hermundsdottir & Aspelund, 2021), with minimum production costs, more competitive output prices will be obtained and ultimately will increase competitiveness.

Method

The aim of this research is to describe rice farming and analyze the technical efficiency of production in farming activities and analyze the influence of factors on technical efficiency in farming activities. The sampling method in this research uses a probability sampling method because this sampling is a sampling technique that provides equal opportunity or opportunity for members of the population to be used as research samples. The type of probability sampling in this research is cluster random sampling because this technique is used if the population does not consist of individuals but rather groups of individuals or clusters. This technique is also used to determine the sample if the object or data to be studied is very broad (Bengtsson, 2016).

The population of lowland rice farmers in Jari Village, Gondang District is 33 out of 52 farmers who are members of POKTAN "Puji Rahayu", this figure is known through several characteristics that have been prepared by researchers. These characteristics include: Farmers who join POKTAN "Puji Rahayu"; Farmers who have more than 10 years of experiencee; Farmers who do not have a side job. Qualitative analysis was used to determine the characteristics of rice farming in Jari Village, Gondang District. Quantitative analysis was carried out to analyze the technical efficiency of rice farming and identify factors that influence the technical efficiency of rice farming using the Data Envelopment Analysis (DEA) approach and Tobit Regression (Miassi et al., 2023). The data obtained was processed using computer assistance (Microsoft Excel 2010 program, DEAP version 2.1, and STATA version 14.2). The results of primary data processing were presented in table form which was then interpreted in the form of a discussion.

In this research, the production inputs that will be estimated are land area (Ha), seeds (Kg), fertilizer (Kg), maintenance drugs (Lt) labor (HOK) and tractor engines (minutes). The output used in this research is rice production whose units are kilograms. If the SEi value = 1, this indicates CRS, and the SEi value <1 identifies scale inefficiency. so that to obtain conditions of decreasing, increasing or constant return to scale, the technical efficiency values of the VRS, CRS models and their scale efficiency are calculated (Zarrin & Brunner, 2023); (Taleb et al., 2019). Factors that influence efficiency can be analyzed using the variables gender, age, access to credit and workforce. The Tobit model used in this research is as follows:

$$EF = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + e \quad (1)$$

Where:
EF: Efficiency Value using the DEA method
β: Parameters
X1: Gender
X2: Farmer's Age
X3: Credit Access
X4: Labor

Result and Descussion

Overview of Rice Farming in Jari Village

Rice farming in Jari Village is one of the livelihoods of the local community. Rice farming activities in Jari Village are carried out regularly according to the planting season pattern, because Jari Village is a rain-fed village, the farmers only plant rice twice. If the climate is uncertain, farmers only plant rice once because agriculture in Jari Village only depends on rainwater. The production aspect is an important aspect in rice farming activities, where this activity starts from land preparation to the harvesting stage(Lakitan et al., 2018); (Qu et al., 2021); (Michael et al., 2023). The first step begins by clearing the land from grass, namely manually using a machete or using a plow machine, then the land is cultivated and prepared for planting. Seedlings are planted manually with a spacing of 15 - 17 cm. (15 cm is the distance between rows and 17 cm is the distance between rice plants). and each hole is filled with 2-3 sticks/hole. The rice maintenance process is carried out by fertilizing, replanting, weeding and controlling pests, diseases and weeds.

After the rice is planted, fertilization activities are then carried out, fertilizing the rice is carried out in Jari Village using Urea and Phosphate chemical fertilizers, the first fertilization is carried out after the plants are ± 10 days old. Then when the plants reach ± 30 days, a second fertilization is applied, giving each plant 5 grams at a distance of 10 cm from the base of the stem. Fertilization is carried out 3 times in one growing season. Then farmers use urea fertilizer, phosphate fertilizer, with doses according to the type of pesticide, control is carried out depending on the condition of the pest plants (weeds). Generally, farmers use 10 liters of water in a handsprayer which is done at intervals of 2-3 days using a handsprayer by spraying it. The disease vulnerability point in rice plants is that it attacks young plants up to ± 45 days. Meanwhile, pest and disease control is carried out when symptoms of attack begin to appear. The pests that often bother rice plants are leaf caterpillars, leaf miners, birds, while rice diseases are downy mildew and leaf spot with the leaves on the plants turning yellow and wilting.

Rice harvest can be done based on visuals if 85% of it starts to turn yellow, some of the flag leaves start to dry out. The optimal age in this case ranges from 30-35 days after flowering evenly. The amount of rice harvest is generally with a total rice planting area of 1.500 M2 in Jari Village, which produces ± 650 Kg. Next are post-harvest activities which include activities namely threshing rice using a sickle and rice threshing machine, cleaning aimed at removing dirt on the grain and other foreign objects in order to improve the quality of the grain, then drying is carried out so that the water content in the grain is reduced to maintain the quality of the grain. Drying is done every 3-4 hours if the weather conditions are hot, then storage can be done by putting it in a sack. After getting the production output in the form of rice with the best quality, the next activity is marketing. Rice marketing is carried out by consumers coming directly to farmers or farmers who deliver it to collectors. The price of rice in Jari Village is currently relatively low, namely Rp. 5.500 /Kg. The payment system is made in cash. Agricultural extension workers in Jari Village exist and are still active once a month. With Poktan, it makes it easier for farmers to get information about agriculture, extension or socialization activities are carried out by Poktan.

Analysis of Technical Efficiency of Rice Farming

Performance analysis was carried out using the Data Envelopment Analysis (DEA) analysis tool. The DEA analysis method was used in this research to understand the influence of various inputs on rice production in Jari Village. The DEA analysis carried out in this research uses the Variable Returns to Scale (VRS) assumption. The aim of using this assumption is to determine whether the proportion of output can change due to adding input in the same proportion. Knowing the condition of the proportion of output which can change due to adding input in the same proportion is different from Constant Return to Scale (CRS) where adding input will result in increasing output in the same proportion. the same one. The results of the DEA analysis will determine the Decision Making Unit (DMU/respondent farmer) which has a technical efficiency of 1.000 with good VRS assumptions. The Efficient DMU will be used as a reference for other DMUs in improving input orientation. The calculation of technical efficiency at the farmer level can be seen in Figure 2.

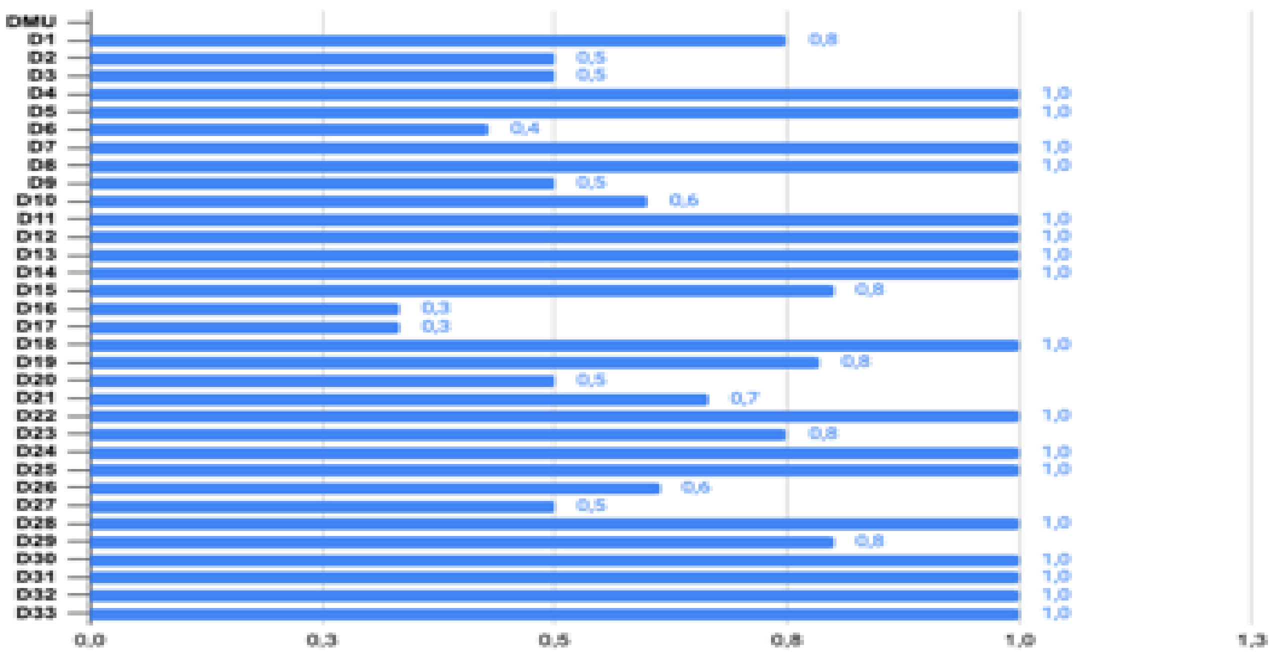

Figure 2. Calculation of Technical Efficiency at Farmer Level

Figure 2 shows that of the 33 DMUs analyzed, 17 of them (52%) are in a technically efficient condition (TE = 1), while the remaining 16 people (48%) are not efficient (TE < 1), which means that some Most farmers are technically efficient. The distribution of technical efficiency values for lowland rice production in Jari Village can be seen in Table 2.

Table 2. Distribution of Technical Efficiency of Rice Businesses with VRSTE Assumptions in Jari Village

	VRSTE efficiency	
Efficiency value	Amount	Presentase
0.24 – 0.49	3	9
0.52 – 0.62	7	21
0.62– 0.70		
0.62-0.70	2	6
0.85 – 0.93	4	12
1.000	17	52
Total	33	100
Average		0.79
Minimum		0.33
Maximum		1.00

The results of the VRSTE assumption analysis in table 5.10 show that respondent farmers who feel that VRS is at full technical efficiency (VRSTE = 1) are 17 DMUs or 53% of the 33 DMUs. The number of DMUs that are not in full technical efficiency consists of 16 DMUs or 47% of the total number of DMUs, which means that the majority of farmers are technically efficient. The distribution of efficiency values in the DMU is between 0.246 – 1.000, with an average value of 0.799, meaning that the distribution of efficiency values feels around the average value. For more details regarding the distribution of DMU technical efficiency values in lowland rice farming, it is presented in Figure 3.

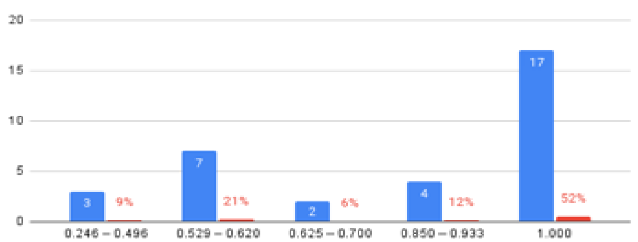

Figure 3. Distribution of DMU Technical Efficiency Values in Rice Farming

In Figure 3, it can be seen that the DMU in lowland rice farming based on technical efficiency values is spread across several groups, namely technical efficiency values of 0.24–0.49 with a total of 3 farmers, 0.52–0.62 with a total of 7 people, 0.62 – 0.70 with a total of 2 farmers. people, 0.85– 0.93 as many as 4 people and with an efficiency value of 1 as many as 17 people. This shows that the majority of DMUs are technically efficient, as shown by the number of DMUs with a technical efficiency value of 1 of 52%. Research results from (Samur et al., 2022), also show that the majority of rainfed lowland rice farmers have achieved technical efficiency, with a total of 94.74%. Meanwhile, several other studies such as (Rondhi et al., 2024), each show results that the majority of rice farmers are technically efficient with a percentage of farmers as high as 71.05%, 30.53% and 50.00%. The large number of efficient farmers cannot be separated from farmers who use fertilizer according to recommendations, farmers who have land areas under 5000 M2 or 0.5 hectares tend to be more efficient than farmers who have large land areas. Because with sufficient land area, farmers can pay more attention to the development of their rice plants and use fertilizers and medicines and plant maintenance appropriately (Mallareddy et al., 2023).

Apart from that, the existence of supporting institutions such as Poktan and field counseling once a month will make it easier for farmers to share information and technology in an effort to increase their productivity. Apart from being caused by internal and external factors of farmers, differences in the level of technical efficiency achieved by farmers are also caused by differences in adaptation strategies carried out by farmers to the impacts of climate change and good perceptions about climate change.

Return to Scale

Analysis carried out using the DEA method can show the condition of return scale for each farmer. This can indicate the condition of the production scale craftsmen when carrying out farming activities. The return to scale table can be seen in Table 3.

Table 3. Distribution of Farming Efficiency Scale in Jari Village

Order Fulfillment Scale	Number of Farmers	Percentage %
Decreasing Return ro Scale (DRS)	0	0
Constant Returns to Scale (CRS)	0	0
Increasing Return to Scale (IRS)	33	100

Table 3 shows the percentage scale (DRS, CRS, IRS) of rice production in this business in Jari Village in one planting season. The scale position is dominated by Increasing Return to Scale, namely an increasing scale. Of the current 33 DMUs, there are 33 farmers who are not yet operating optimally. DEA's study of rice farming in Ds Jari produced findings covering various size conditions. With 33 responses from farmer respondents, rice farming has the largest percentage of Increasing Return to Scale (IRS) producers. DRS is a situation where the DMU's production scale is too large so it requires an increase in production scale to be reduced, while IRS is a DMU that has not reached maximum production so it needs to increase its business scale (additional input).

Peer Group

Peer is one or more DMUs that have best practices or the most efficient conditions so that they can be used as a reference for inefficient DMUs to increase their efficiency value (Borrás et al., 2023). The peer group table in this research can be seen in Table 4.

Table 4. Peer Group Results

DMU	Peer		
1	4	30	
2	30		
3	30		
4	4		
5	4	30	
6	30		
7	30	4	
8	22	4	30
9	30		
10	30		
11	22	30	
12	22	30	
13	22		
14	30		
15	22	30	4
16	30		
17	30		
18	30		
19	30	22	
20	30	4	
21	30		
22	22		
23	30	4	
24	24		
25	30	4	
26	30	22	
27	30	4	
28	22	30	4
29	22	30	
30	30		
31	30	4	
32	22	4	30
33	22	30	

This peer group table is a reference for other DMUs, for DMUs that are not yet efficient, refer to DMUs that are already efficient. For example, DMU 5 refers to DMU 4 and DMU 30, where this DMU is a DMU that is considered relevant to DMU 2. It can be seen in table 5.12 that it can be seen which DMUs are used as references by DMUs that are in the inefficient category. The DMU with the largest number of peer groups, or what could be called an efficient benchmark, is a DMU that has an efficiency value for existing factors as a whole, so that it can be used as the most stable DMU in utilizing input into output. It can also be said that this DMU will remain relatively efficient in the future unless major changes in input or other conditions occur.

Excessive Input Spread (SLACK)

Table 5. Results of Excessive Input Distribution (SLACK)

Variable	Average Slack Value	Number of DMUs
Land area	1045.45	28
Fertilizer	5.84	26
seed	60.01	13
Maintenance Medication	0.40	16
Labor	3.81	24
Tractor engine	94.00	11

Based on the results of calculations using the DEA method, it was found that the average input slack value was spread across all input variables used by the respondent farmers. In general, the use of rice farming inputs from respondent farmers is not technically efficient, because the slack values for all variables used are not met. The average excess input value of all respondent farmers can be seen in table 13, showing that farmers who use excess input values as many as 28 rice farmers in Jari Village can still reduce the land area by 1.045.45 hectares, rice seeds by 5.84 kg, fertilizer by 5.84 kg. 60.01 Kg, 0.40 liters of plant maintenance medicine, 3.81 HOK workers, and 94,00 minutes of tractor engines. Land area, fertilizer, and use of tractor engines are production inputs that have the largest excess input value compared to the others. Farmers who are efficient have achieved the zero slack assumption for all variables (production input) used. Respondent farmers who are inefficient have slack input values on several variables (production input). This shows that inefficient farmers still have advantages in terms of using production inputs to produce output at the same level.

Socio-Economic Factors that Influence the Technical Efficiency of Rice Farming

To determine the best follow-up strategy, observations regarding socio-economic variables that can influence the output efficiency of interviewed farmers, such as gender, age, access to credit and labor (within the family and outside the family), must be carried out. The variables used in Tobit regression can be seen in Table 6.

Table 6. Variables Used in Tobit Regression

Unit Variables	Average	Minimum	Maximum
Age (years)	57	38	72
Labor (HOK)	26	18	75
Dummy Variables	Category	Total Farmers	Percentage
Gender	1 = Man	31	93.40
	0=Woman	2	6.60
Credit Access	0= Bank	16	48.50
	1 = Private	17	51.50

From table 6 it can be seen that in analyzing the factors that influence the technical efficiency of rice businesses, the technical efficiency obtained from DEA calculations will be regressed on several predetermined socio-economic variables. Meanwhile, the results of the Tobit regression can be seen in Table 7.

Table 7. Tobit Regression Results for Rice Farming

	Coefficient	Probability Pr > | t |)
Gender Type	77.01	0.58
Age (years)	-5.74	0.12**
Credit Access	-2.18	0.97
Work (HOK)	-17.81	0.00*

*Significant at 1% significance level
**Significant at 15% level of significance

The findings of the Tobit regression analysis regarding the impact of socio-economic factors on business production efficiency are presented in Table 7. From this table, age has a significant influence on technical efficiency with a coefficient value of -5.74 and a probability value of 0.124 with a real level of 15%, which means that the older you are. The age of the farmer will reduce the technical efficiency of the farming carried out by the farmer. Younger farmers tend to be more open to new technology and innovation in agriculture, so they tend to be more efficient in adopting modern practices that can increase yields and reduce production costs (Ruzzante et al., 2021); (Miine et al., 2023); (Diao et al., 2023). Apart from that, they have more energy and motivation to try new things and are able to adapt to changes that occur in the agricultural sector. The results of this research are in line with research conducted by (Purbiati et al., 2024); (Tirtalistyani et al., 2022); (Moore et al., 2024)where it is assumed that farmers of productive age will be better at cultivating in rice fields, as well as faster in adopting innovations that will be accepted even though they have minimal experience.

However, this research is not in line with research conducted by (Munz & Schuele, 2022); (Wąs et al., 2021); (Ton et al., 2017), this research shows a prob value > | t | which is higher than α = 15% (the desired real level). This insignificant condition means that the influence of the farmer variable cannot be concluded. This is because farmers have their own cultivation system and it has been passed down from generation to generation, so younger farmers do not necessarily have lower production efficiency than older farmers. Another variable that has a significant influence on the technical efficiency of rice farming is the number of workers, labor has a coefficient value of -17.81928 and a probability value of 0.000, namely with a significance level of 1% which means that every time there is additional labor in rice farming, it will reduce The level of technical efficiency of farming, this is because if the use of excessive labor is not balanced with the land owned by farmers, it will increase input costs in rice production. If input and output are not balanced, it will affect the efficiency of a farming business.

Conclusion

Rice planting carried out by respondent farmers starts from land preparation, seed and seed preparation, planting, weeding, fertilizing, spraying, harvesting and marketing. The use of production inputs from respondent farmers is still not in accordance with the recommendations given by extension workers. The efficiency of lowland rice farming is technically efficient at 52%, and 48% is not technically efficient. Inefficiency is caused by a combination of input use that is not optimal and the use of production input from respondent farmers is still not in accordance with the recommendations given by extension workers. There are 17 technically efficient rice farmers in Jari Village out of the total respondents, with an average efficiency value of 0.799. Rice farmers in Jari Village can still reduce the land area by 1.045.456 hectares, rice seeds by 5.84 Kg, fertilizer by 60.01 Kg, plant maintenance medicine by 0.40 liters, labor by 3.81 HOK, and tractor engines by 94.00 minutes to achieve efficiency. his. The factors that significantly influence the efficiency of pado rice farming are age and labor. Younger farmers tend to be more open to new technology and innovation in agriculture, so they tend to be more efficient in adopting modern practices that can increase yields and reduce production costs. Meanwhile, if the labor factor is used excessively and does not match the capacity of the land owned by the farmer, it will increase input costs in rice production. If input and output are not balanced, it will affect the efficiency of a business.

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Conflicts of Interest

The authors declare no conflict of interest

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