

EFFICIENCY ANALYSIS OF LOWLAND RICE FARMING USING A STOCHASTIC FRONTIER PRODUCTION FUNCTION APPROACH. CASE STUDY IN GOLO SEPANG VILLAGE, BOLENG DISTRICT, WEST MANGGARAI REGENCY

(Analisis Efisiensi Usahatani Padi Sawah dengan Pendekatan Fungsi Produksi Stochastic Frontier: Studi Kasus di Desa Golo Sepang, Kecamatan Boleng, Kabupaten Manggarai Barat)

Lusia Oktaviana Unar¹, Fredrik L. Benu², Ida Nurwiana³, Damianus Adar⁴

^{1,2,3,4}Agribusiness Study Program, Faculty of Agriculture, Nusa Cendana University

Corresponding Author: ovinunar@gmail.com

Received: 3rd June, 2026

Accepted: 6th June, 2026

ABSTRACT

This study aims to analyze the factors influencing lowland rice production as well as the technical and economic efficiency of lowland rice farming in Golo Sepang Village, Boleng District, West Manggarai Regency. The research location was selected purposively (purposive sampling), and data were collected using a survey method. The analysis employed the Cobb–Douglas frontier production function and the stochastic frontier approach. The results show that seed, pesticides, and labor have positive and significant effects on lowland rice production, while fertilizer has a negative and insignificant effect. Age, farming experience, and household size significantly reduce technical inefficiency, whereas other sources of income increase technical inefficiency. Farmer group membership does not have a significant effect on technical inefficiency. The average technical efficiency is 0.664, allocative efficiency is 0.065, and economic efficiency is 0.040, indicating that lowland rice farming has not yet achieved economic efficiency.

Keywords: Cobb–Douglas frontier production function, economic efficiency, lowland rice, stochastic frontier.

ABSTRAK

Penelitian ini bertujuan untuk menganalisis faktor-faktor yang memengaruhi produksi padi sawah serta efisiensi teknis dan ekonomi usahatani padi sawah di Desa Golo Sepang, Kecamatan Boleng, Kabupaten Manggarai Barat. Lokasi penelitian dipilih secara sengaja (*purposive sampling*), dan data dikumpulkan menggunakan metode survei. Analisis dilakukan dengan menggunakan fungsi produksi *frontier* Cobb–Douglas dan pendekatan *stochastic frontier*. Hasil penelitian menunjukkan bahwa benih, pestisida, dan tenaga kerja berpengaruh positif dan signifikan terhadap produksi padi sawah, sedangkan pupuk berpengaruh negatif dan tidak signifikan. Usia, pengalaman usahatani, dan jumlah anggota rumah tangga secara signifikan mengurangi inefisiensi teknis, sementara sumber pendapatan lain meningkatkan inefisiensi teknis. Keanggotaan dalam kelompok tani tidak berpengaruh signifikan terhadap inefisiensi teknis. Nilai rata-rata efisiensi teknis adalah 0,664, efisiensi alokatif 0,065, dan efisiensi ekonomi 0,040, yang menunjukkan bahwa usahatani padi sawah tersebut belum mencapai efisiensi ekonomi.

Kata kunci: Fungsi Produksi Frotier Cobb–Douglas, efisiensi ekonomi, padi sawah, stochastic frontier

INTRODUCTION

The agricultural sector has a strategic role in the Indonesian economy, particularly in food provision and increasing farmer income. The food crop subsector, especially rice, is a major commodity that plays an important role in national food security, including in East Nusa Tenggara (NTT) Province (Badan Pusat Statistik, 2024). Nevertheless, rice production in NTT in recent years has declined due to the reduction in harvested area, although productivity has shown a relatively small increase and remains below the potential yield of superior rice varieties, which can reach 8–10 tons per hectare. West Manggarai Regency is one of the rice production centers in NTT, with Boleng District as an area contributing a relatively large harvested area. However, lowland rice productivity in Boleng District remains lower than in several other districts in the same regency, indicating efficiency problems in the management of lowland rice farming. Fluctuations in rice production in this area are influenced by various technical constraints, such as seed quality, fertilizer and pesticide use, and dependence on hired labor, as well as nontechnical constraints such as relatively older farmer age and limited managerial capacity.

Golo Sepang Village is one of the villages in Boleng District with considerable lowland rice potential, but it faces problems of productivity and production efficiency. In certain periods, the village also experienced planting failure due to drought, which affected the decline in harvested area and lowland rice production (Pos Kupang, 2024). The low efficiency of production factor use indicates that lowland rice farming in this area has not yet achieved optimal technical and economic efficiency.

Efficiency in the use of production factors is an important indicator of farming success. Technical efficiency reflects the ability of farmers to produce maximum output from available inputs, while economic efficiency is a combination of technical efficiency and allocative or price efficiency (Nurlela et al., 2017). Low technical and allocative efficiency will affect farmers' income and profit. Therefore, research is needed to analyze the factors influencing production as well as the level of technical and economic efficiency of lowland rice farming as a basis for formulating policies and strategies to increase productivity and farmer welfare sustainably.

RESEARCH METHODS

This study was conducted in September 2025 in Golo Sepang Village, Boleng District, West Manggarai Regency, with the consideration that the village has a potential lowland rice area of four thousand hectares and that the majority of its population works as farmers. The population consisted of 1,700 people, and the sampling method used was simple random sampling with a tolerable error level of $(0.1)^2$. Thus, the sample size was 94 respondents. The research method used was a survey method. The data sources were primary and secondary data. Primary data were obtained through interviews with respondents based on a prepared questionnaire, while secondary data were obtained from BPS, related agencies, and literature reviews.

To answer the first objective, namely the factors influencing lowland rice production, the Cobb–Douglas frontier production function analysis was used.

The formula is as follows:

$$Y = \alpha X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} e^u$$

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + v_i - u_i$$

where Y = total production (kg), X1 = land area (ha), X2 = quantity of seed used (kg), X3 = quantity of fertilizer (kg), X4 = pesticide (liter), X5 = labor (HOK), beta0 = intercept, beta1, beta2, beta3, beta4, beta5 = estimated parameters, and $v_i - u_i$ = disturbance error (v_i) and technical inefficiency effect (u_i) in the model.

The technical inefficiency method used in this study refers to the technical inefficiency effects model developed by Coelli (1998).

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \varepsilon_1$$

where u_i = technical inefficiency effect, α_0 = constant, Z1 = age (years), Z2 = experience (years), Z3 = education (years), Z4 = number of household members, Z5 = other sources of income, and Z6 = farmer group (dummy variable), with 1 = active and 0 = inactive.

To answer the second objective, namely analyzing the technical and economic efficiency levels of lowland rice farming, the stochastic frontier production function was used. The technical efficiency value can be calculated using the equation described in the source document. ET refers to group technical efficiency; n refers to the number of farmers or observation units; Y1 refers to farmers' actual production or harvest; and frontier production refers to maximum potential production derived from the frontier function. Technical efficiency values range between 0 and 1, where farming activities are considered efficient if the technical efficiency level equals 1 (ET = 1).

The cost function can be formulated using the dual of the Cobb–Douglas production function and the input cost function. Thus, the cost function includes $\alpha_{ij} = r_j b_j$ and $r = (b_j)$, with C = total production cost; K = constant derived from production function parameters; the product of input prices (P) for each type (j) raised to the power of a_j ; actual observed output; and R = cost elasticity parameter with respect to output.

Furthermore, economic efficiency analysis was calculated through the equation shown in the source document. EE refers to economic efficiency; C* refers to the ratio of minimum total production cost; C refers to actual total production cost; Y_i refers to farmer actual output; P_i refers to input prices used by farmers; C_i refers to the cost for the i-th farmer; and $u_i = 0$ refers to the ideal condition without technical inefficiency, meaning the farmer is highly efficient. According to Anggaraini et al. (2016), economic efficiency (EE) is

defined as the ratio between the observed minimum total production cost and actual total production cost (C), as shown in the equation above.

The EE value ranges from $0 < EE < 1$. The formula for individual allocative or price efficiency (EH) in lowland rice farming is:

$$EH = EE / ET$$

where EH = price efficiency, EE = economic efficiency, and ET = technical efficiency. The efficiency criteria are: $E > 1$ = not yet efficient, $E = 1$ = efficient, and $E < 1$ = inefficient.

RESULTS AND DISCUSSION

General Description of the Research Location

Golo Sepang Village is located in Boleng District, West Manggarai Regency, East Nusa Tenggara Province, with an area of approximately 84.25 km² and a population of approximately 3,951 people. This village is the capital of Boleng District and is located around 48 km from the administrative center of West Manggarai Regency, Labuan Bajo. Geographically, Golo Sepang Village consists of lowland and coastal areas and borders Nanga Kantor Village to the east, Tanjung Boleng Village to the west, Pontianak Village to the north, and Sepang Village to the south. The economy of the Golo Sepang Village community is dominated by agriculture, fisheries, and livestock. Agricultural activities are still traditional, with main commodities including rice, maize, mung beans, and peanuts, while cattle and pig farming serve as additional sources of income. The village is supported by basic infrastructure, educational facilities up to senior high school level, and health services in the form of a community health center and integrated health service posts.

Respondent Characteristics

The results showed that the average age of respondents was 47.60 years, with average farming experience reaching 24 years, reflecting relatively good farming experience. Respondents' formal education level was dominated by senior high school graduates at 43.6%. Respondents' participation in nonformal education was relatively low, especially extension activities, which were mostly attended only once (39.4%). The average number of household dependents was 4 people, while the average other source of income of respondents was Rp6,151,213.

Factors Influencing Lowland Rice Farming Production

This analysis aims to determine the extent of the influence of each production factor on lowland rice output and to measure the technical efficiency level of the farming activities carried out by farmers. The parameter estimation of the Stochastic Frontier production function using the MLE method is presented in Table 1.

Table 1. Estimation Results of Factors Influencing Lowland Rice Production

Variable	Parameter	Coefficient	Standard Error	Sig.
Constant	α	6.829835	0.4295586	15.899***
Land Area	β_1	-0.000011	0.0000010	-11.551***
Seed	β_2	0.609856	0.1079751	5.648***
Fertilizer	β_3	-0.000004	0.0000020	-1.939 Ns
Pesticide	β_4	0.529799	0.1144777	4.627***
Labor	β_5	0.000004	0.0000018	2.482**
Sigma-squared / Gamma		-0.045518 / -0.064586	0.0089799 / 0.4693373	5.068*** / 0.137 Ns
Log likelihood function		11.10143		
LR Test of the one-sided error		73.72583		

Source: Data analysis results using Frontier 4.1c, 2025.

Notes: *** significant at alpha = 1% or alpha = 0.01 (t table = 2.64); ** significant at alpha = 5% or alpha = 0.05 (t table = 1.99); Ns = non-significant.

The estimation results of the Stochastic Frontier model show that the sigma-squared (σ^2) value is significant at the 1% level, indicating that the model has good accuracy and reliability in explaining variations in lowland rice production. The gamma (γ) value of 0.137 and its non-significance indicate that technical inefficiency contributes only slightly to production variation, while most variation is influenced by random factors such as weather and environmental conditions. Nevertheless, the significant Likelihood Ratio Test at the 5% level confirms that technical inefficiency still exists in lowland rice farming, so efforts to improve efficiency remain relevant. This finding is consistent with Coelli et al. (2005), who stated that although the effect of technical inefficiency is relatively small, its presence still affects differences in production performance among farmers.

The Log Likelihood Function value of 11.10 indicates a good model fit to the data. The production function estimation shows that the constant has a positive and significant effect, indicating the influence of fixed factors such as land fertility and irrigation systems, as also reported by Battese et al. (1995). The land area variable has a negative and significant effect on production, indicating that wider land management has not been balanced with optimal input use and management. This finding is in line with Sari et al. (2020), who found that farmers with smaller land areas tend to be more efficient because crop management and supervision are carried out more intensively.

Seed, pesticide, and labor variables have positive and significant effects on lowland rice production, indicating that productive and protective input use plays an important role in increasing output. This result is consistent with Handayani et al. (2023), who emphasized that quality seed and appropriate pest control can increase productivity and bring production closer to the frontier. Conversely, the fertilizer variable does not have a significant effect on production, indicating that fertilization has not been carried out efficiently. This is in line with Rivanda et al. (2018), who stated that inappropriate dosage and timing of fertilizer application cause low production response.

Analysis of Technical and Economic Efficiency of Lowland Rice Farming

Technical Efficiency Analysis

Technical efficiency values describe farmers' ability to optimally manage production factors such as land, seed, fertilizer, pesticide, and labor. The technical efficiency estimation results for lowland rice farming are presented in Table 2.

Table 2. Estimation Results of Technical Efficiency Levels

Efficiency Level	Number of Farmers	Percentage (%)
>0.30	1	1.06
0.31–0.40	6	6.38
0.41–0.50	14	14.89
0.51–0.60	20	21.28
0.61–0.70	18	19.15
0.71–0.80	11	11.70
0.81–0.90	7	7.45
0.91–0.99	17	18.09
Total	94	100
Average		0.664
Minimum		0.278
Maximum		0.993

Source: Data analysis results using Frontier 4.1c, 2025.

The estimation results show that the average technical efficiency level of lowland rice farming in Golo Sepang Village is 0.664, indicating that farming has not yet achieved technical efficiency. Farmers are only able to achieve about 66.4% of the maximum production potential, so there remains an opportunity to increase efficiency by 33.6% through improvements in the use of production inputs.

The maximum technical efficiency value of 0.993 and minimum value of 0.278 show a fairly wide variation in efficiency among farmers, reflecting differences in managerial ability in managing production factors. Most farmers are at the medium efficiency level (0.51–0.80), while some have approached efficient conditions and others remain at low efficiency levels.

This finding indicates the need for efforts to improve technical efficiency through extension, farm management training, and the application of appropriate technology so that the use of production inputs becomes more optimal. In addition, differences in technical efficiency among farmers are presumed to be influenced by socioeconomic characteristics, which are further analyzed through the technical inefficiency model.

Table 3. Estimation Results of Factors Influencing Technical Inefficiency

Variable	Coefficient	Standard Error	Sig.
Constant	1.2810839	0.6897040	1.857 Ns
Age (Z1)	-0.5093215	0.1094141	-4.654***
Farming Experience (Z2)	-0.0000054	0.0000019	-2.759***
Education (Z3)	-0.6742506	0.1653171	-4.078***
Number of Household Members (Z4)	-0.0000074	0.0000033	-2.244**
Other Sources of Income (Z5)	0.5567047	0.1277994	4.356***
Farmer Group (Z6)	0.0000032	0.0000018	1.739 Ns
sigma-squared (σ^2)	-0.0455185	0.0089799	5.068***
Gamma (γ)	-0.0645861	0.4693373	0.137 Ns
LR Test of the one-sided error	73.725839		

Source: Data analysis results using Frontier 4.1c, 2025.

Notes: *** significant at alpha = 1% or alpha = 0.01 (t table = 2.64); ** significant at alpha = 5% or alpha = 0.05 (t table = 1.99); Ns = non-significant.

The estimation results of the inefficiency effects model show that the stochastic frontier model used is appropriate for explaining variations in technical inefficiency in lowland rice farming in Golo Sepang Village, as indicated by the significant sigma-squared (σ^2) value and the significant Likelihood Ratio Test. The nonsignificant gamma (γ) value indicates that variations in lowland rice production are influenced more by random factors than by technical inefficiency.

Age, farming experience, education level, and number of household members have negative and significant effects on technical inefficiency. This finding indicates that improvements in human capital quality, experience, and availability of family labor can increase the technical efficiency of farming. This result is in line with Ali et al. (2022), who emphasized that farmer experience and education play an important role in increasing rice production efficiency.

Conversely, other sources of income have a positive and significant effect on technical inefficiency, indicating that farmer involvement in non-agricultural activities tends to reduce focus and the quality of farm management. This finding is consistent with Harmini et al. (2025), who found that farmers with off-farm income have lower technical efficiency. Meanwhile, farmer group membership does not have a significant effect on technical inefficiency. This finding is consistent with Hakim et al. (2021), who stated that institutional

membership does not automatically improve technical efficiency unless followed by effective institutional functions in extension and technology transfer.

Allocative and Economic Efficiency

The analysis of economic efficiency (EE) and allocative efficiency (AE) was obtained by analyzing production inputs based on input prices prevailing at the farmer level. This analysis used the Cobb–Douglas stochastic frontier production function as the basis of analysis (Nikmah et al., 2013). The frontier cost function, or isocost frontier, was obtained from the derivation of the frontier production function. The resulting frontier cost function is presented through the efficiency estimates below.

Table 4. Allocative Efficiency (AE) and Economic Efficiency (EE) Levels of Lowland Rice Farming in Golo Sepang Village, Boleng District, West Manggarai Regency, 2025

Efficiency Level	AE Farmers	AE (%)	EE Farmers	EE (%)
0.00–0.30	94	100	94	100
0.31–0.40				
0.41–0.50				
0.51–0.60				
0.61–0.70				
0.71–0.80				
0.81–0.90				
0.91–1.00				
Total	94	100	94	100
Average		0.065		0.040
Max.		0.142		0.050
Min.		0.042		0.034

Source: Frontier 4.1c analysis data, 2025.

The analysis results show that the average allocative efficiency (AE) of lowland rice farming in Golo Sepang Village is 0.065, with a maximum value of 0.142 and a minimum value of 0.042, while the average economic efficiency (EE) is 0.040. These values indicate that farmers have only achieved 6.5% of the optimal allocative efficiency level and 4% of the optimal economic efficiency level, so there is still a very large potential for efficiency improvement. All respondent farmers (100%) are in the AE and EE range of 0.00–0.30, which is classified as highly inefficient, indicating that the combination of production input use has not fulfilled the principles of cost minimization and profit maximization.

The low levels of allocative and economic efficiency reflect the lack of alignment between technical efficiency and price efficiency in lowland rice farming practices. This condition is presumed to be influenced by limited farmer knowledge and ability in cost planning and management, traditional input allocation patterns that do not consider relative prices and marginal productivity, limited access to information and extension, and fluctuations in input and output prices. This finding is in line with Nurwansyah et al. (2021) and Maharani et al. (2018), who concluded that lowland rice farming in Indonesia is generally not yet allocatively and economically efficient. Therefore, interventions are needed through strengthening agricultural extension, improving cost management capacity, and providing price information and appropriate production technology in order to encourage input use that is more economical, efficient, and oriented toward increasing farmer income.

CLOSING

Conclusion

Based on the results of the study on the efficiency analysis of lowland rice farming in Golo Sepang Village, Boleng District, West Manggarai Regency, several conclusions were obtained. Production factors show that seed, pesticide, and labor have positive and significant effects on lowland rice production, while fertilizer has a negative and insignificant effect, indicating that its use by farmers has not been optimal in terms of type or dosage.

Socioeconomic factors show that age, farming experience, and number of household members significantly reduce technical inefficiency, while other sources of income increase technical inefficiency. Farmer group

membership does not have a significant effect, indicating that the role of farmer groups in improving farmers' technical capacity has not functioned effectively.

The efficiency level shows that the average technical efficiency is 0.664, while allocative and economic efficiency are 0.065 and 0.040, respectively. This indicates that lowland rice farming is still far from efficient conditions, especially in terms of input use based on cost considerations.

Recommendations

Farmers are expected to optimize the use of production factors according to technical recommendations and reduce excessive fertilizer use so that efficiency and harvest quality can increase.

Agricultural extension workers are advised to strengthen extension and assistance related to input management, cost calculation, and efficient farming management.

Local governments are expected to provide production facilities and agricultural infrastructure in a timely manner and expand access to market information in order to support efficient and sustainable production.

REFERENCES

- Ali, S., Khan, M., & Shah, S. (2022). Does Education And Farming Experience Affect Technical Efficiency Of Rice Crop Growers Evidence From Khyber Pakhtunkhwa, Pakistan.
- Anggaraini, N., Harianto, & Anggaraeni, L. (2016). Efisiensi Teknis, Alokatif Dan Ekonomi Pada Usahatani Ubikayu Di Kabupaten Lampung Tengah, Provinsi Lampung. *Jurnal Agribisnis Indonesia*, 4(1), 43–56. <https://ejournal.ugm.ac.id/jurnalagribisnis/article/view/12345>
- Badan Pusat Statistik Provinsi Nusa Tenggara Timur (2024). Produksi Padi Menurut Kabupaten/Kota (Ton GKG). <https://ntt.bps.go.id/id/statistics-table/2/OTI5IzI=/Produksi-Padi-Menurut-Kabupaten-Kota.html>
- Battese, G. E., & Coelli, T. J. (1995). A Model For Technical Inefficiency Effects In A Stochastic Frontier Production Function For Panel Data. *Empirical Economics*, 20(2), 325–332. <https://doi.org/10.1007/BF01205442>
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (1998). *An Introduction To Efficiency And Productivity Analysis*. Springer. <https://dl.icdst.org/pdfs/files/3a67240be4e2274e4c95655ec16931de.pdf>
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An Introduction To Efficiency And Productivity Analysis* (2nd Ed.). Springer.
- Hakim, R., Haryanto, T., & Sari, D. W. (2021). Technical Efficiency Among Agricultural Households And Determinants Of Food Security In East Java, Indonesia. <https://www.nature.com/articles/S41598-021-83670-7>
- Handayani, S., Wibowo, R., & Prasetyo, A. (2023). Pengaruh Penggunaan Benih Unggul Terhadap Produktivitas Padi Organik Di Provinsi Lampung. *Jurnal Sosial Ekonomi Pertanian*, 18(2), 101–110.
- Harmini, H., Harianto, F., Feryanto, F., Tinaprilla, N., & Maryono, M. (2025). Impacts Of Off-Farm Income On Technical Efficiency Of Rice Farming: Correction To Bias. *Jurnal Ekonomi Dan Studi Pembangunan*, 14(2). <https://citeus.um.ac.id/jesp/vol14/iss2/5>
- Maharani, A. D., Prasetyo, E., & Setiawan, B. M. (2018). Analisis Efisiensi Ekonomi Penggunaan Faktor-Faktor Produksi Pada Usahatani Padi Di Kelompok Tani Sidomakmur I Kecamatan Pati Kabupaten Pati.
- Nikmah, A., Fauziyah, E., & Rum, M. (2013). Analisis Produktivitas Usahatani Jagung Hibrida Di Kabupaten Sumenep. *Agriekonomika*, 2(2), 96–107.
- Nurlela, S., Hartoyo, S., & Kusnadi, N. (2017). Analisis Efisiensi Teknis, Alokatif, Dan Ekonomi Usahatani Padi Sawah Di Indonesia. *Jurnal Agro Ekonomi*, 35(2), 89–102.
- Nurwansyah, I., Ilsan, M., & Amran, F. D. (2021). Analisis Efisiensi Alokatif Penggunaan Unsur Produksi Usahatani Padi Sawah Tadah Hujan (Studi Kasus Di Desa Limampocoe, Kecamatan Cenrana, Kabupaten Maros).
- Poskupang. (2024). <https://kupang.tribunnews.com/2024/02/07/Dampakkekeringa-502-Petani-Di-Manggarai-Barat-Gagal-Tanam>
- Rivanda, R., Prasmatiwati, F. E., & Situmorang, S. (2015). Analisis Faktor-Faktor Yang Mempengaruhi Produksi Padi Sawah Di Kabupaten Karawang. *Jurnal Agribisnis*, 9(2), 87–96.
- Rivanda, R., Haryono, D., & Murniati, K. (2018). Efisiensi Penggunaan Pupuk Pada Usahatani Padi Sawah. *Jurnal Penelitian Pertanian Terapan*, 18(1), 12–20.

Sari, D. P., Suhartini, & Widodo, S. (2020). Pengaruh Luas Lahan Terhadap Efisiensi Teknis Usahatani Padi Sawah Di Kabupaten Sragen. *Jurnal Ekonomi Pertanian Dan Agribisnis*, 4(1), 65–74.