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Technical Efficiency in Rice Production Among Large-Scale Rice Farmers in Chiang Rai Province

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Abstract

This study aims to analyze the technical efficiency in rice production and the factors contributing to technical inefficiency among large-scale rice farmers in Chiang Rai Province. Utilizing secondary data from the 2022/23 rice cultivation season, the research involved a sample of 400 farmers, determined using the Taro Yamane formula. The analysis of technical efficiency was conducted using the Stochastic Production Frontier method with a Cobb-Douglas production function, while factors affecting technical inefficiency were examined through Ordinary Least Squares (OLS) regression. The findings indicate that significant factors influencing rice yield at a statistical level of 0.01 include fertilizer application and pesticide usage, whereas seed quantity showed significance at a level of 0.05. The technical efficiency analysis revealed that most farmers operate at a very high level of efficiency ($0.801 \leq TE \leq 1.000$), with an average technical efficiency score of 0.898. Additionally, the study identified four key variables impacting technical inefficiency: farmers' experience in rice production, frequency of training received, area cultivated, and educational level. To enhance rice production efficiency, it is recommended that farmers apply fertilizers and pesticides appropriately, select high-quality seeds, engage in continuous training for cultivation techniques, manage their cultivated areas effectively, and seek further knowledge on resource management and agricultural technology to increase both yield and overall farming efficiency.

Keywords: Technical Efficiency; Rice Production; Large-scale Rice Farmer; Agricultural Technology

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Introduction

Rice is a crucial economic crop in Thailand, serving as both a staple food for the population and the country's leading agricultural export commodity. It plays a significant role in regional economic stability, as it is the primary agricultural product occupying the largest cultivated area, accounting for 45.20% of the total agricultural land in the country. Approximately 4.3 million households engage in rice farming, representing 74.40% of all agricultural households (Office of Agricultural Economics, 2024). Additionally, rice exports contribute significantly to national income, with Thailand being one of the world's major rice producers and exporters. In the 2023/24 cultivation season, Thailand ranked sixth globally in rice production volume, following China, India, Bangladesh, Indonesia, and Vietnam, which account for 28%, 26%, 7%, 6%, and 5% of global production, respectively (U.S. Department of Agriculture, 2024). Furthermore, Thailand is the second-largest rice exporter worldwide, trailing only India, amidst competition from countries such as Vietnam, Pakistan, and the United States (Chowcharoensuk, 2019).

In Northern Thailand, rice cultivation ranks second nationally after the Northeastern region, with a cultivated area of 15,033,850 rai. Chiang Rai Province leads in rice cultivation within the North, covering 1,293,948 rai with an average yield of 555 kilograms per rai (Office of Agricultural Economics, 2023). Despite having the largest cultivation area in Northern Thailand, Chiang Rai's production levels are lower than those of other provinces like Lamphun and Chiang Mai. Notably, while Chiang Mai and Lamphun have smaller cultivated areas, their average yields per rai surpass those of Chiang Rai. Historical data from the production years 2017/18 to 2020/21 indicate a declining trend in average yields for Chiang Rai's main rice crop-recorded at 580 kg/rai for both 2017/18 and 2018/19; dropping to 549 kg/rai in 2019/20; and slightly recovering to 556 kg/rai in 2020/21 (Digital Government Development Agency Public Organization, 2020). This decline aligns with reports from the Chiang Rai Social Situation Report by the Policy and Academic Group of the Chiang Rai Social Development and Human Security Office, which highlights a downward trend in average yields correlating with regional economic conditions (Chiang Rai Social Development and Human Security Office, 2021).

Factors contributing to reduced production may include climatic uncertainties such as droughts and floods, pest infestations, soil degradation, and rising production costs due to increasing prices for inputs like seeds, fertilizers, pesticides, and labor. Additionally, many farmers lack adequate skills and knowledge regarding effective pest management and optimal fertilizer application rates. These challenges may stem from inefficiencies in production processes (Raiyasawat, 2018). Supporting this notion are studies by Hakim et al. (2020) and Aboaba (2020), which utilized Stochastic Frontier Analysis (SFA) and Tobit regression models to identify significant positive impacts on rice yield from input variables such as seed quality and pest control measures. Furthermore, factors such as farmers' experience in rice cultivation, educational attainment of household heads, training participation in rice production techniques, and water management practices were found to influence technical inefficiency in production (Kouser & Mushtaq, 2010; Goldman, 2013; Ogundele & Okoruwa, 2014).

Given this context, there is a notable gap in research focusing on the analysis of production efficiency among large-scale rice farmers participating in government-supported programs aimed at assisting agricultural producers. Therefore, this study aims to investigate the technical efficiency of rice production among large-scale farmers in Chiang Rai Province. The objectives include analyzing technical efficiency levels and identifying factors contributing to technical inefficiency within this group. The results of this analysis will provide insights that can help farmers enhance productivity or reduce production costs while

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also serving as a basis for informed decision-making regarding cultivation practices. Additionally, these findings will assist policymakers in formulating appropriate strategies to support sustainable rice production initiatives moving forward.

Literature Review

The assessment of technical efficiency using Stochastic Frontier Analysis (SFA) has become a widely adopted method in contemporary research. This analytical approach utilizes two primary types of data: panel data and cross-sectional data. Panel data offers significant advantages over cross-sectional data due to its larger sample size, which enhances the precision of the analysis. The relationship can be represented mathematically as follows (Coelli et al., 2005):

$$Iny_{it} = f(X_{it};\ \beta) + e_{it} \tag{1}$$

where f denotes an appropriate functional form (such as Cobb-Douglas or Translog), y_{it} represents the output of unit i at time t, X_{it} includes the factors affecting the output of unit i during time t, β is the vector of parameters to be estimated, and e_{it} is the error term, which can be decomposed as follows:

$$e_{it} = v_{it} - u_{it} \tag{2}$$

Here, u_i represents controllable errors such as personal characteristics, while v_i captures uncontrollable errors such as disease outbreaks, pest infestations, droughts, and rainfall variability.

Additionally, technical efficiency (TE) can be estimated by measuring the ratio of the output y_{it} (in Equation 1) to the maximum possible output $(\mathbf{y_{max}} = \mathbf{exp}(\mathbf{x_{it}};\ \boldsymbol{\beta}) * \mathbf{v_{it}})$ calculated under optimal environmental conditions. By employing an output-oriented measure of technical efficiency, this value represents the ratio of the observed output to the potential output along the stochastic frontier output. This measure indicates the level of technical efficiency of the production unit and can be expressed in the following equation format (Omar & Fatah, 2021).

$$\mathbf{TE} = \frac{\mathbf{Y_{it}}}{\mathbf{exp\,(f(x_{it};\beta)) * exp\,(v_{it})}} = \frac{\mathbf{exp\,(f(x_{it};\beta)) * exp\,(v_{it}) * exp\,(-u_{it})}}{\mathbf{exp\,(f(x_{it};\beta)) * exp\,(v_{it})}} \tag{3}$$

$$\mathbf{TE} = \mathbf{exp\,(-u_{it})} \tag{4}$$

The value of technical efficiency (TE) ranges from 0 to 1, where a TE value close to 1 indicates high efficiency, while lower values signify inefficiencies in the production process. A review of existing literature reveals that SFA has been frequently employed to analyze agricultural sectors, with Maximum Likelihood Estimation (MLE) commonly used alongside factors influencing technical inefficiency. These influencing factors are typically categorized into two groups: those affecting output levels-such as seed quantity, fertilizer application, production costs, labor, and machinery (Wu, 2020; Khan et al., 2022; Chandel et al., 2022), and those impacting technical efficiency itself such as farmer age, experience, educational level, and training participation (Ho & Shimada, 2019; Chikezie et al., 2020; Omar & Fatah, 2021). Consequently, this research will utilize Stochastic Frontier Analysis (SFA), focusing on variables affecting output levels including seed quantity, fertilizer application, pesticide usage, labor input, machinery costs, and overall production expenses. Additionally, factors influencing technical inefficiency will include farmer age, experience in rice cultivation, frequency of training received, cultivated area size, educational attainment, and cultivation practices. This comprehensive approach aims to provide insights into both productivity levels and underlying inefficiencies within rice production systems.

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Methodology

This study utilizes secondary data regarding rice production for the 2022/23 cultivation season from large-scale rice farmers in Chiang Rai Province, comprising a sample of 400 farmers selected from a total of 7,191 registered large-scale rice producers in the region (Chiang Rai Agricultural Office, 2024). The sample size was determined using the Taro Yamane formula (Yamane, 1967) at a 95% confidence level.

Data analysis concerning technical efficiency was conducted using the Stochastic Production Frontier (SPF) method, specifically employing the Cobb-Douglas production function. The estimation of coefficients for various factors affecting rice yield was performed using Maximum Likelihood Estimation (MLE) as outlined by Aigner et al. (1977). The mathematical representation of the model is as follows:

$$\ln y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + (v_i - u_i) \qquad (5)$$

Where:

ln = natural logarithm
y_i = rice yield (kilograms/rai)
X_1 = quantity of rice seeds used (kilograms/rai)
X_2 = amount of fertilizer applied (kilograms/rai)
X_3 = labor and machinery input (hours/rai)
X_4 = quantity of pesticides used (liters/rai)
X_5 = production costs (Baht/rai)
β_0 = constant term
$\beta_1, \ldots, \beta_5$ = coefficients representing the elasticity of each input
v_i = error term attributable to external uncontrollable factors such as weather conditions, temperature, and rainfall
u_i = error term attributable to controllable factors by the farmer

To analyze factors influencing technical inefficiency (Technical Inefficiency: TI), Ordinary Least Squares (OLS) regression was employed, represented by the following equation:

$$TI = \delta + \delta_1 lnZ_1 + \delta_2 lnZ_2 + \delta_3 lnZ_3 + \delta_4 lnZ_4 + \delta_5 lnZ_5 + e \qquad (6)$$

Where:

TI = technical inefficiency
Z_1 = age of the farmer (years)
Z_2= years of experience in rice production
Z_3= number of training sessions attended
Z_4 = cultivated area size (rai)
Z_5 = educational level of the farmer (categories: below primary education, primary education, lower secondary education, upper secondary/Vocational Certificate, Associate Degree/Vocational Diploma, Bachelor's Degree, higher than Bachelor's Degree)
δ = parameter coefficients
e = error term

This methodology aims to provide a comprehensive analysis of both technical efficiency and the factors contributing to inefficiencies in rice production among large-scale farmers in Chiang Rai Province. By employing robust statistical techniques and established economic

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models, this study seeks to identify key determinants affecting productivity and inform strategies for enhancing agricultural practices.

Results

4.1 Statistical Hypothesis Testing

In this study, statistical hypothesis testing was conducted to identify the appropriate production function between the Cobb-Douglas Function and the Translog Function using the Likelihood Ratio (LR) test. The results indicated that the Cobb-Douglas Function is suitable for this research, as evidenced by the likelihood-ratio statistic of -4.950, which is less than the critical value of χ^2 at 18.307 with 10 degrees of freedom (df = 10) at a significance level of 0.05. This outcome leads to the acceptance of the null hypothesis and the rejection of the alternative hypothesis (Table 1).

Table 1. Hypothesis Testing Statistics for Production Function Form Using Likelihood Ratio

Hypothesis	LR test	df	$\chi^2_{0.05}$	Conclusion
$H_0: \beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$ (Cobb-Douglas) $H_1: \beta_1 + \beta_2 + \beta_3 + \beta_4 \neq 1$ (Translog)	-4.950	10	18.307	Accept H_0

Subsequently, to estimate the model for assessing technical inefficiency in production, another hypothesis test was performed using the LR statistic. The calculated LR statistic was found to be 27.324, which exceeds the critical value of 8.761 from Kodde and Palm (1986), with 4 degrees of freedom (df = 4) at a significance level of 0.05. This result indicates a rejection of the null hypothesis and acceptance of the alternative hypothesis (Table 2). Therefore, it can be concluded that technical inefficiency is present in the production model.

Table 2. Hypothesis Testing Statistics for Technical Inefficiency Model Using Likelihood Ratio

Hypothesis	LR test	df	$\chi^2_{0.05}$	Conclusion
$H_0: \gamma = 0$ (*No inefficiency effect*) $H_1: \gamma \neq 0$ (*Inefficiency effect present*)	27.324	4	8.761	Reject H_0

These findings underscore the significance of incorporating technical inefficiency effects into the production model, thereby enhancing its accuracy and relevance in evaluating rice production efficiency among large-scale farmers in Chiang Rai Province. By employing robust statistical methods and adhering to rigorous hypothesis testing protocols, this study provides a comprehensive analysis of technical efficiency and inefficiencies within agricultural production systems. The results contribute valuable insights for policymakers and practitioners aiming to improve agricultural productivity through targeted interventions that address identified inefficiencies.

4.2 Estimation of the Stochastic Production Frontier

The estimation of the factors influencing rice production efficiency was conducted using the Stochastic Production Frontier (SPF) approach. The variance parameter, σ_s^2, was estimated at 0.036, which is statistically significant at the 0.01 level. This finding indicates that the production function is influenced by other factors beyond those included in the model. The analysis revealed several statistically significant factors affecting rice yield at varying significance levels. Specifically, the coefficient for fertilizer application was found to be 0.005, suggesting that a 1% increase in fertilizer usage, holding other variables constant, would result in a 0.005% increase in rice yield. Similarly, the coefficient for pesticide

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application was 0.044, indicating that a 1% increase in pesticide usage would lead to a 0.044% increase in rice yield, with other factors held constant. In terms of seed quantity, the coefficient was statistically significant at the 0.05 level, with a value of 0.008. This implies that increasing the quantity of rice seeds by 1% would result in a corresponding increase in rice yield of 0.008%, assuming all other variables remain unchanged. Conversely, production costs had a coefficient of -0.062, also significant at the 0.05 level, suggesting that a 1% increase in production costs would decrease rice yield by 0.062%, with other factors held constant. Notably, labor input did not significantly impact technical efficiency (Table 3).

Table 3. Parameter Estimates from Stochastic Production Frontier Model Using Maximum Likelihood Estimation (MLE)

Variable	Coefficient	Standard error	t-ratio
Constant	5.923	0.104	56.952
Quantity of Rice Seeds (kg/rai)	0.008	0.003	2.667**
Quantity of Fertilizer (kg/rai)	0.005	0.009	0.556***
Quantity of Pesticides (liters/rai)	0.044	0.014	3.143***
Labor and Machinery (hours/rai)	0.004	0.006	0.667
Production Costs	-0.062	0.028	-2.231**
variance parameter			
sigma-squared : $\sigma_{\varepsilon}^2 = \sigma_v^2 + \sigma_u^2$	0.036	0.010	3.600***
gamma : $\gamma = \sigma_u^2/\sigma_v^2$	0.792	0.083	9.542***

Note: ***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level.

4.3 Technical Efficiency Analysis

The analysis of technical efficiency in rice production revealed that the maximum technical efficiency score among large-scale farmers in Chiang Rai Province was recorded at 0.979, while the minimum score was found to be 0.512. On average, the technical efficiency score across all farmers was calculated to be 0.898, indicating a very high level of technical efficiency in production. Despite this high average efficiency score, it is noteworthy that full technical efficiency (TE = 1) was not achieved; instead, farmers operated at approximately 89.80% of their potential output capacity, suggesting that there remains an opportunity for improvement of about 10.20% under existing technological and production conditions. When analyzing individual farmer efficiencies, it was observed that a significant majority exhibited very high technical efficiency scores ranging from 0.801 ≤ TE ≤ 1.000, accounting for approximately 79% of the sample population. The next category included farmers with high efficiency scores ranging from 0.601 ≤ TE ≤ 0.800, representing about 20.75%. Only a small fraction (approximately 0.25%) fell into the moderate efficiency category with scores between 0.401 ≤ TE ≤0.600 (Table 4).

Table 4. Technical Efficiency Levels Among Large-Scale Rice Farmers

Efficiency Level	Technical efficiency scores	Frequency	Percentage
Very Low	0.000−0.200	-	-
Low	0.201−0.400	-	-
Medium	0.401−0.600	1	0.25
High	0.601−0.800	83	20.75
Very High	0.801−1.000	316	79.00
Total		400	100.00
Max	**0.979**		
Min	**0.512**		
Mean	**0.898**		

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4.4 Analysis of Factors Affecting Technical Inefficiency in Rice Production

The analysis of factors influencing technical inefficiency in rice production was conducted using a linear model and multiple regression analysis via Ordinary Least Squares (OLS). The results indicated several statistically significant variables affecting the technical inefficiency of large-scale rice farmers at varying confidence levels. Notably, the experience of farmers in rice production emerged as a significant factor at the 0.01 confidence level, with a coefficient of -0.046. This implies that for every additional year of experience in rice production, technical inefficiency decreases by 0.046. This negative relationship suggests that increased experience among farmers correlates with improved production efficiency. Another critical factor identified was the number of training sessions attended by farmers, which also significantly influenced technical inefficiency at the 0.01 level, with a coefficient of -0.623. This indicates that for each additional training session attended, technical inefficiency decreases by 0.623. Thus, greater participation in training programs is associated with enhanced production efficiency. Furthermore, the educational level of farmers was found to significantly impact technical inefficiency at the 0.05 confidence level, with a coefficient of -0.286. This result indicates that an increase in educational attainment by one level reduces technical inefficiency by 0.286. Higher education levels likely facilitate better knowledge acquisition and adoption of efficient production techniques. Conversely, the size of cultivated land positively correlated with technical inefficiency, with a coefficient of 0.072 at the 0.05 confidence level. This suggests that an increase in cultivated area by one rai leads to a 0.072 increase in technical inefficiency. The larger the area under cultivation, the more challenging it becomes for farmers to manage resources effectively. Lastly, while farmer age was included as a variable in the analysis, it did not demonstrate a statistically significant effect on technical inefficiency (Table 5).

Table 5. Estimation of Factors Influencing Technical Inefficiency

Variables	Coefficient	Standard Error	t-ratio
Constant	0.847	0.862	0.982
Age of Farmer (years)	0.009	0.010	0.961
Experience in Rice Production (years)	-0.046	0.017	-2.756***
Educational Level	-0.286	0.155	-1.843**
Number of Training Sessions	-0.623	0.526	-1.184***
Size of Cultivated Area (rai)	0.072	0.429	0.168**
Log likelihood		-15.61	
R-Squared		0.73	
Durbin – Watson Stat		2.24	

Note: ***Significant at the 0.01 level; **Significant at the 0.05 level; *Significant at the 0.10 level.

5. Summary and Discussion

The estimation of factors affecting rice production efficiency through the Stochastic Production Frontier model revealed that significant variables at the 0.01 confidence level included fertilizer application and pesticide usage. This indicates that increases in both fertilizer and pesticide quantities, while holding other variables constant, lead to higher rice yields. These findings align with the research conducted by Omar & Fatah (2021), which similarly noted a positive impact of these inputs on production levels. Additionally, rice seed quantity was statistically significant at the 0.05 level, confirming its critical role in influencing rice yield as supported by Muteti et al. (2023).

The analysis of technical efficiency scores indicated that the majority of large-scale farmers in Chiang Rai Province operate at a very high technical efficiency level ($0.801 \leq$ TE

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≤ 1.000), accounting for 79% of the sample. The average technical efficiency score for this group was found to be 0.898, suggesting that while farmers are performing well, they are not achieving full efficiency (TE = 1). This implies a potential for improvement of 10.20% under existing production conditions, consistent with findings from Puapong (2024), which reported an average efficiency score of 0.9169, indicating that farmers could enhance their output by approximately 8.31% using current technologies and inputs.

The investigation into factors contributing to technical inefficiency identified four key variables: (1) **Farmers' Experience**: An increase in years of experience correlated with reduced technical inefficiency, indicating that more experienced farmers tend to produce more efficiently. (2) **Training Participation**: The number of training sessions attended by farmers also significantly decreased technical inefficiency, suggesting that ongoing education enhances production practices. This aligns with Somkum and Wana's (2020) assertion that increased farming experience and training lead to improved production efficiency. (3) **Cultivated Area**: Conversely, an increase in cultivated land area was associated with higher technical inefficiency due to challenges in management and oversight, corroborating findings from Panyatui et al. (2023). (4) **Educational Level**: Higher educational attainment among farmers was linked to lower technical inefficiency, supporting Billah's (2022) conclusion that education facilitates better access to knowledge and improved farming techniques.

However, factors such as farmer age, land tenure status, and cultivation methods did not demonstrate statistically significant effects on technical inefficiency.

6. Recommendations

6.1 Farmers should prioritize the appropriate quantity and methods of using fertilizers and pesticides to maximize yields while minimizing environmental impacts. Additionally, government agencies should provide education on safe and effective use of these inputs to enhance production efficiency.

6.2 Access to quality seeds suited for various cultivation conditions should be promoted to enable farmers to achieve optimal production levels.

6.3 Farmers are encouraged to participate regularly in training or activities related to rice cultivation to gain new knowledge and improve their skills in managing crops effectively.

6.4 The government should offer guidance on efficient land management practices, such as labor-saving systems or technology utilization, to improve overall production efficiency.

6.5 Further educational opportunities for farmers should be supported, ensuring they have access to knowledge about modern agricultural practices, which will contribute to sustainable improvements in production efficiency.

By implementing these recommendations, stakeholders can work towards enhancing the productivity and sustainability of rice farming in Chiang Rai Province, ultimately contributing to food security and economic stability in the region.

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