Technical Efficiency and Managerial Implications of Para Rubber Production in Upper Northern Thailand

ประสิทธิภาพทางเทคนิคและข้อเสนอแนะเชิงบริหารในการผลิตยางพาราในภาคเหนือของประเทศไทย

Dr. Itthirit Wongchai
Assistant Professor,
School of Economics and Investment, Bangkok University
ดร. อิทธิฤทธิ์ วงศ์ไชย
ผู้ช่วยศาสตราจารย์ คณะเศรษฐศาสตร์และการลงทุน มหาวิทยาลัยกรุงเทพ
E-mail: Itthirit.w@bu.ac.th

วันที่ได้รับต้นฉบับบทความ : 18 สิงหาคม 2568
วันที่แก้ไขปรับปรุงบทความ : 8 พฤศจิกายน 2568
วันที่ตอบรับตีพิมพ์บทความ : 27 พฤศจิกายน 2568

Abstract

Rubber is a vital economic crop for Thailand, which is one of the world's major producers and exporters of natural rubber. This has led to a continuous expansion of rubber production, particularly in the Upper Northern region, where rubber plantations are widespread. However, it has been found that the yield per rai in this region has significantly declined compared to other parts of the country. This study aims to examine the characteristics and measure the technical efficiency of rubber production, as well as to analyze the factors contributing to technical inefficiency in rubber cultivation in the Upper Northern region of Thailand. Data were collected from 400 rubber farmers across five districts—Chiang Kham, Phu Sang, Chiang Dao, Fang, and Chiang Khong—located in the provinces of Phayao, Chiang Mai, and Chiang Rai. The analysis employed the Stochastic Production Frontier approach to estimate technical efficiency, while the Tobit model was used to identify the factors affecting technical inefficiency in rubber production at the 90% and 95% confidence levels. The results revealed that the technical efficiency of rubber farming, as measured by Stochastic Frontier Analysis (SFA), was very high (0.901–1.000) among most farmers in Chiang Kham (Phayao), Chiang Dao (Chiang Mai), and Chiang Khong (Chiang Rai). In contrast, farmers in Phu Sang (Phayao) and Fang (Chiang Mai) demonstrated high levels of technical efficiency (0.701–0.900). Significant factors contributing to technical inefficiency included the number of training sessions attended, farming experience, employment of tapping labor, and the amount of rainfall in the cultivation area. The findings of this research can be used as a guideline to drive development and enhance technical efficiency, while also offering management recommendations for rubber production in the northern region of Thailand.

Keywords: Rubber, Technical Efficiency, Stochastic Frontier, Upper northern region

บทคัดย่อ

ยางพาราเป็นพืชเศรษฐกิจที่สำคัญของประเทศไทย ซึ่งเป็นหนึ่งในประเทศผู้ผลิตและส่งออกยางธรรมชาติรายใหญ่ของโลก ส่งผลให้มีการขยายตัวของการผลิตยางพาราอย่างต่อเนื่อง โดยเฉพาะในพื้นที่ภาคเหนือตอนบนที่มีการปลูกยางพาราอย่างแพร่หลาย อย่างไรก็ตาม พบว่า ผลผลิตต่อไร่ในพื้นที่ดังกล่าวมีแนวโน้มลดลงอย่างชัดเจนมากกว่าภูมิภาคอื่นของประเทศ การศึกษานี้มีวัตถุประสงค์เพื่อ ศึกษาลักษณะและวัดประสิทธิภาพทางเทคนิคของการผลิตยางพารา ตลอดจนวิเคราะห์ปัจจัยที่ส่งผลต่อความไม่มีประสิทธิภาพทางเทคนิค ในการผลิตยางพาราในพื้นที่ภาคเหนือ ตอนบนของประเทศไทย โดยเก็บรวบรวมข้อมูลจากเกษตรกรชาวสวนยางจำนวน 400 ราย ใน 5 อำเภอ ได้แก่ อำเภอเชียงคำ อำเภอภูซาง อำเภอเชียงดาว อำเภอฝาง และอำเภอเชียงของ ในจังหวัดพะเยา เชียงใหม่ และเชียงราย การวิเคราะห์ข้อมูลดำเนินการโดยใช้

แนวทางเส้นพรมแดนการผลิตแบบสุ่ม เพื่อประมาณค่าประสิทธิภาพทางเทคนิค และใช้ แบบจำลองโทบิต เพื่อวิเคราะห์ปัจจัยที่มีอิทธิพลต่อความไม่มีประสิทธิภาพทางเทคนิคในการผลิตยางพารา โดยกำหนดระดับความเชื่อมั่นทางสถิติที่ร้อยละ 90 และร้อยละ 95 ผลการวิจัยพบว่า ประสิทธิภาพทางเทคนิคในการทำสวนยางวัดโดยวิธี Stochastic Frontier Analysis (SFA) อยู่ในระดับ สูงมาก (0.901–1.000) ในกลุ่มเกษตรกรส่วนใหญ่ของอำเภอเชียงคำ (จังหวัดพะเยา), อำเภอเชียงดาว (จังหวัดเชียงใหม่) และอำเภอเชียงของ (จังหวัดเชียงราย) ขณะที่อำเภอภูซาง (จังหวัดพะเยา) และอำเภอฝาง (จังหวัดเชียงใหม่) มีระดับประสิทธิภาพทางเทคนิคในเกณฑ์สูง 0.701–0.900) สำหรับปัจจัยที่ส่งผลต่อความไม่มีประสิทธิภาพทางเทคนิคอย่างมีนัยสำคัญ ได้แก่ จำนวนครั้งที่ได้รับการอบรม ประสบการณ์ในการทำสวนยาง การจ้างแรงงานกรีดยาง และปริมาณน้ำฝนในพื้นที่ ผลการวิจัยนี้สามารถใช้เป็นแนวทางในการขับเคลื่อนเพื่อการพัฒนาและการปรับปรุงประสิทธิภาพทางเทคนิค รวมถึงเป็นข้อเสนอแนะเชิงบริหารในการผลิตยางพาราในภาคเหนือของประเทศไทย

คำสำคัญ: ยางพารา ประสิทธิภาพทางเทคนิค เส้นพรมแดนเชิงเฟ้นสุ่ม ภาคเหนือตอนบน

Introduction

Rubber remains a vital economic crop for Thailand and the global economy, primarily due to its extensive applications in the automotive, medical, and industrial sectors. The global demand for natural rubber has continued to rise in recent years, driven by economic recovery, infrastructure development, and increasing demand for electric vehicles. According to the Office of Agricultural Economics (2024), Thailand remains the world's largest producer and exporter of natural rubber, accounting for approximately one-third of global output. The total production of natural rubber in Thailand was projected to reach 4.93 million tons in 2025, representing an annual increase of about 2.9% from 2024, while exports were estimated at 4.2 million tons (Krungsri Research, 2024; Sunsirs, 2024). In the domestic context, the Upper Northern provinces have become an increasingly important region for rubber cultivation, expanding rapidly due to government promotion policies and farmers' diversification away from traditional crops. The major rubber-producing provinces in this region include Chiang Mai, Chiang Rai, Phayao, Lamphun, Lampang, Nan, and Mae Hong Son. However, despite the growing plantation area, yields in this region have fluctuated and, in some years, declined more sharply than in other regions of the country. Earlier data from the OAE (2021) indicated that yields fell from 182 kg/rai in 2018 to 178 kg/rai in 2020, while more recent reports estimated the regional yield at approximately 205 kg/rai in 2025 (Sunsirs, 2024). These variations may be attributed to changes in climatic conditions, soil fertility, and differences in production technology and management practices among farmers. Given these conditions, improving the technical efficiency of rubber production in the Upper Northern region is essential for ensuring the sector's sustainability and competitiveness. Therefore, the objectives of this study are (1) to measure the technical efficiency of para rubber production using the Stochastic Frontier Analysis (SFA) approach, and (2) to identify factors contributing to technical inefficiency through a Tobit regression model. The findings will provide valuable insights into resource allocation and technology adoption for smallholder farmers, thereby contributing to productivity enhancement, income improvement, and long-term sustainability of rubber production in the region. This study focuses on smallholder rubber farms located in the Upper Northern region of Thailand, encompassing the provinces of Chiang Mai, Chiang Rai, and Phayao. The research employs a stochastic frontier production-function approach to estimate technical efficiency, complemented by a Tobit model to analyze the determinants of technical inefficiency.

Literature Review

Production

Production involves three interrelated components: (1) inputs, which are the resources used to produce goods and services; (2) the production process, referring to the series of steps that combine inputs and resources to create outputs; and (3) outputs, which are the results or products derived from the production process (Phaithun, 1998). The relationship among these components is represented by the production function (Coelli et al., 2005), which can be expressed as:

$$y = f(x)$$

Where: y = Output

x = Inputs

In the context of Thailand's rubber sector, statistical evidence over the past five years demonstrates changing patterns in cultivation and yield performance. According to the Office of Agricultural Economics (2024), the country's rubber plantation area expanded from approximately 20.46 million rai in 2019 to 22.08 million rai in 2023, while total production fluctuated between 4.6–4.9 million tons annually. However, average yields have declined from 237 kg/rai in 2019 to 213 kg/rai in 2023, reflecting a gradual reduction in productivity despite area expansion (Krungsri Research, 2024; Sunsirs, 2024). The national average yield reported by the Department of Agriculture (2023) remains around 270 kg/rai, suggesting that northern regions lag behind the national mean. This trend indicates possible inefficiencies in resource utilization, climatic limitations, or technological disparities among smallholder farmers. Such quantitative evidence highlights the importance of analyzing the efficiency dimension of rubber production to understand how farmers in emerging regions—especially the Upper North—can optimize resource use under current technological and environmental constraints.

Measuring Technical Efficiency

Technical efficiency refers to the ability of a production unit to maximize output given a set of inputs (Farrell, 1957). The conceptual foundation of efficiency measurement originates from Farrell's (1957) frontier framework, later developed through stochastic and deterministic approaches. Two common analytical tools for measuring efficiency are Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). This study adopts the SFA approach using the Cobb–Douglas production function, which considers both random errors and inefficiency components (Meeusen & van Den Broeck, 1977; Aigner et al., 1977; Drinkwater & Harris, 1999; Kumbhakar & Lovell, 2000; Coelli et al., 2005; Songsrirote & Singhapreecha, 2007). The method is widely applied in agricultural economics, offering robust estimates of technical efficiency. For instance, Abdul-Rahaman (2016) evaluated the technical efficiency of small-scale cotton farmers in northern Ghana using SFA and reported that age, education level, family size, and farming experience significantly affected efficiency. Similarly, Pattarakamolsen and Chaovanapoonphol (2018) applied SFA to garlic production in Fang District, Chiang Mai Province, and found high levels of efficiency influenced by household-head education, cultivated area, access to water sources, and farming experience. Integrating these perspectives with recent statistical data provides empirical justification for examining technical efficiency in para-rubber production within Thailand's upper northern provinces, where productivity stagnation persists despite continued expansion in plantation area.

Research Methodology

1. Sample Group

The sample group in this study consists of 400 rubber farmers selected from five districts located in the upper northern region of Thailand: Chiang Khong (Chiang Rai Province), Fang and Chiang Dao (Chiang Mai Province), and Chiang Kham and Phu Sang (Phayao Province).

A probability sampling method, specifically stratified random sampling, was employed to ensure that all major rubber-growing areas in the upper northern region were proportionally represented. Each district was treated as a stratum based on the total number of registered rubber farmers in that district, according to the records of the Rubber Authority of Thailand (2024).

The proportionate allocation technique was applied to determine the number of samples in each district, using the following formula:

$$n_i = \frac{N_i}{N} \times n$$

where : n_i = number of samples in stratum i,

N_i = total number of rubber farmers in stratum i,

N = total population of rubber farmers in all study areas,

n = total sample size (400 farmers).

Data Collection

Primary Data

Primary data were obtained through structured interviews using a pretested questionnaire administered to 400 rubber farmers. The questionnaire covered socioeconomic characteristics, input–output variables, and production conditions related to rubber cultivation.

Secondary Data

Secondary data were collected from published articles, academic journals, research reports, and official documents from relevant institutions such as the Office of Agricultural Economics (OAE) and the Rubber Authority of Thailand (RAOT). These data were used to support the literature review and to define variables in the econometric models.

Data Analysis

Data analysis was divided into two parts: (1) General analysis of the farmers' data, and (2) Analysis of technical efficiency and the factors contributing to technical inefficiency in rubber production. The details are as follows:

2. Descriptive Statistics

General characteristics of the sample were analyzed using descriptive statistics, including frequency, percentage, mean, and standard deviation.

3. Econometric Analysis

A two-step procedure was applied:

- Step 1: Estimation of technical efficiency using the Stochastic Frontier Analysis (SFA) with the Cobb–Douglas production function and Maximum Likelihood Estimation (MLE) via Frontier 4.1 software.

- Step 2: Examination of determinants of technical inefficiency using the Tobit regression model, where the inefficiency scores obtained from the first step served as
the dependent variable.

Variables Used in the Analysis

- Stochastic Frontier Analysis (SFA)

Input:

- Cultivated area
- Number of rubber trees
- Amount and cost of chemical fertilizer
- Amount and cost of urea fertilizer
- Age at which tapping starts
- Tapping period
- Number of laborers
- Use of decomposing agents for leaves

Output:

- Rubber yield

- Tobit Regression Analysis

Independent Variable:

- Number of training sessions attended
- Farmers' experience
- Use of customized fertilizer
- Area characteristics
- Planting distance
- Employment of tapping labor
- Rainfall amount
- Prevalence of rubber diseases
- Government policy support

Dependent Variable

- Technical inefficiency (TI) score obtained from the SFA model

Research Findings

General Information on Farmers

The study revealed that the general characteristics of rubber farmers in the five districts of Northern Thailand's Upper Northern region are as follows: Most of the farmers are male, with an average age of 50 years or older. The average educational level is primary school. The average cultivated area is between 11-20 rai, with an average income from rubber plantations ranging between 50,001-100,000 THB per year. The farmers have an average experience of 11-15 years (Table 1).

Table 1 Summary of General Information on Farmers by District

Area / List	Chiang Rai	Phayao		Chiang Mai	
	Chiang Khong	Chiang Kham	Phu Sang	Fang	Chiang Dao
Sample Size	180	70	70	40	40
Average Age (years)	41-50	>50	>50	>50	>50
Education Level	Primary	Primary	Primary	Primary	Primary
Cultivated Area (Rai)	11-20	11-20	≤ 10	11-20	11-20
Income (Baht/Year)	50,001-100,000	50,001-100,000	50,001-100,000	<50,000	50,001-100,000
Experience (years)	≤ 5	11-15	≤ 5	11-15	11-15
Total		**400**			

Source: Based on the findings of the survey

Results of Technical Efficiency Measurement of Rubber Plantation Using SFA Method

The technical efficiency of rubber plantations was measured using the SFA method in the following northern provinces of Thailand: Chiang Rai Province (Chiang Khong District), Phayao Province (Phu Sang District, and Chiang Kham District), Chiang Mai Province (Fang District, and Chiang Dao District)

Chiang Rai Province

Chiang Khong District

The technical efficiency of farmers is notably high, ranging from 0.901 to 1.000, with 168 farmers (93.33% of the sample) falling within this range. The next most common efficiency level was classified as high (0.701–0.900), comprising 12 farmers (6.67%). When considering the overall technical efficiency of rubber plantations in Chiang Khong District, the maximum technical efficiency observed was 0.957, and the minimum was 0.705 (with a standard deviation of 0.041). The average technical efficiency of rubber plantations was 0.939, or 93.90% of the total potential technical efficiency. This implies that the most effi cient production could achieve 100% of the total technical efficiency [TE=1]. However, the average technical efficiency in Chiang Khong District, Chiang Rai Province, reached only 93.90%, indicating that the use of production factors is not yet fully optimized. Farmers could potentially increase their technical efficiency by an additional 6.10% (Table 2).

Table 2 Technical Efficiency Levels in Rubber Plantation, Chiang Rai Province

Technical Efficiency Level (TE)		Chiang Rai Province (Chiang Khong District)	
		Number of Individuals	Percentage
Very Low	[0.000-0.300]	0	0.00
Low	[0.301-0.500]	0	0.00
Moderate	[0.501-0.700]	0	0.00
High	[0.701-0.900]	12	6.67
Very High	[0.901-1.000]	168	93.33
Total		180	100.00
Mean ($\bar{X}$)		0.939	
Maximum (Max)		0.957	
Minimum (Min)		0.705	
Standard Deviation (S.D.)		0.041	

Source: Derived from calculations.

Phayao Province

1. Chiang Kham District

The technical efficiency of rubber plantations in Fang District, Chiang Mai Province, as estimated using the Stochastic Frontier Analysis (SFA) method show that most farmers in Chiang Kham district exhibited very high technical efficiency levels (0.901-1.000). A total of 66 farmers, accounting for 94.29%, fell into this category, while four farmers (5.71%) were classified under the high efficiency level (0.701-0.900).

When considering the overall technical efficiency of rubber plantations in Chiang Kham District, the maximum efficiency observed was 0.995, and the minimum was 0.712 (with a standard deviation of 0.050). The average technical efficiency of rubber plantations was 0.982, or 98.20% of the total potential technical efficiency. This implies that the most efficient production could achieve 100% of the total technical efficiency [TE=1]. However, the average technical efficiency in Chiang Kham District reached only 98.20%, indicating that the use of production factors is not yet fully optimized. Farmers could potentially increase their technical efficiency by an additional 1.80% (Table 3).

2. Phu Sang District

Most farmers in Phu Sang District exhibited high technical efficiency levels (0.701-0.900). A total of 50 farmers, accounting for 71.43%, fell into this category. The medium efficiency level (0.501-0.700) included 17 farmers (24.29%), while two farmers (2.85%) were in the low efficiency category (0.301-0.500), and only one farmer (1.43%) achieved very high efficiency (0.901-1.000). Considering the overall technical efficiency of rubber plantations in Phu Sang District, the maximum efficiency observed was 0.917, and the minimum was 0.311 (with a standard deviation of 0.117). The average technical efficiency of rubber plantations was 0.743, or 74.30% of the total potential technical efficiency. This implies that the most efficient production could achieve 100% of the total technical efficiency [TE=1]. However, the average technical efficiency in Phu Sang District reached only 74.30%, indicating that the use of production factors is not yet fully optimized. Farmers could potentially increase their technical efficiency by an additional 25.70% (Table 3).

Table 3 Technical Efficiency Levels (TE) in Rubber Plantation, Phayao Province

Technical Efficiency Level (TE)		Phayao Province			
		Phu Sang District		Chiang Kham District	
		Number of Individuals	Percentage (%)	Number of Individuals	Percentage (%)
Very Low	[0.000-0.300]	0	0.00	0	0.00
Low	[0.301-0.500]	2	2.85	0	0.00
Moderate	[0.501-0.700]	17	24.29	0	0.00
High	[0.701-0.900]	50	71.43	4	5.71
Very High	[0.901-1.000]	1	1.43	66	94.29
Total		**70**	**100.00**	**70**	**100.00**
Mean ($\bar{X}$)		0.743		0.982	
Maximum (Max)		0.917		0.995	
Minimum (Min)		0.311		0.712	
Standard Deviation (S.D.)		0.117		0.117	

Source: Derived from calculations.

Chiang Mai Province

1. Fang District

The technical efficiency of rubber plantations in Fang District, Chiang Mai Province, as estimated using the Stochastic Frontier Analysis (SFA) method, indicates that the majority of farmers demonstrate high efficiency levels (0.701–0.900). A total of three farmers, accounting for 82.50%, fall into this category. Following this, four farmers (10.00%) achieved very high efficiency (0.901-1.000), while three farmers (7.50%) were classified under the medium efficiency level (0.501-0.700). When considering the overall technical efficiency of rubber plantations in Fang District, the maximum efficiency observed was 0.911, and the minimum was 0.568 (with a standard deviation of 0.080). The average technical efficiency was 0.801, or 80.10% of the total potential technical efficiency. This implies that the most efficient production could achieve 100% of the total technical efficiency [TE=1]. However, the average technical efficiency in Fang District reached only 80.10%, indicating that the use of production factors is not yet fully optimized. Farmers could potentially increase their technical efficiency by an additional 19.90% (Table 4).

2. Chiang Dao District

The technical efficiency of rubber plantations in Chiang Dao District, Chiang Mai Province, measured using the SFA method, indicates that most farmers exhibited very high technical efficiency levels (0.901-1.000). A total of 3four farmers, accounting for 85.00%, fall into this category. Following this, four farmers (10.00%) were classified under the high efficiency level (0.701-0.900), while two farmers (5.00%) exhibited medium efficiency (0.501-0.700). When considering the overall technical efficiency of rubber plantations in Chiang Dao District, the maximum efficiency observed was 0.947, and the minimum was 0.684 (with a standard deviation of 0.061). The average technical efficiency was 0.911, or 91.10% of the total potential technical efficiency. This implies that the most efficient production could achieve 100% of the total technical efficiency [TE=1]. However, the average technical efficiency in Chiang Dao District reached only 91.10%, indicating that the use of production factors is not yet fully optimized. Farmers could potentially increase their technical efficiency by an additional 8.90% (Table 4).

Table 4 Technical Efficiency Levels (TE) in Rubber Plantation, Chiang Mai Province

Technical Efficiency Level (TE)		Chiang Mai Province			
		Fang District		Chiang Dao District	
		Number of Individuals	Percentage (%)	Number of Individuals	Percentage (%)
Very Low	[0.000-0.300]	0	0.00	0	0.00
Low	[0.301-0.500]	0	0.00	0	0.00
Moderate	[0.501-0.700]	3	7.50	2	5.00
High	[0.701-0.900]	33	82.50	4	10.00
Very High	[0.901-1.000]	4	10.00	34	85.00
Total		**40**	**100.00**	**40**	**100.0**

Table 4 Technical Efficiency Levels (TE) in Rubber Plantation, Chiang Mai Province (Cont)

Technical Efficiency Level (TE)	Chiang Mai Province			
	Fang District		Chiang Dao District	
	Number of Individuals	Percentage (%)	Number of Individuals	Percentage (%)
Mean ($\bar{X}$)	0.801		0.911	
Maximum (Max)	0.911		0.947	
Minimum (Min)	0.568		0.684	
Standard Deviation (S.D.)	0.080		0.061	

Source: Derived from calculations.

Overall Efficiency Measurement Across the Five Districts

The technical efficiency of rubber plantations across five key districts in the provinces of Phayao, Chiang Mai, and Chiang Rai was measured using the Stochastic Frontier Analysis (SFA) method. The study found that three districts achieved very high levels of technical efficiency: Chiang Khong District in Chiang Rai Province, Chiang Kham District in Phayao Province, and Chiang Dao District in Chiang Mai Province, with average technical efficiency scores of 0.9392, 0.9111, and 0.9817, respectively. The other two districts, Fang District in Chiang Mai Province and Phu Sang District in Phayao Province, achieved high levels of efficiency, with average technical efficiency scores of 0.801 and 0.743, respectively (as shown in Figure 1). However, the average efficiency scores across all five districts indicate that the use of production factors is not yet fully optimized. This suggests that farmers could still enhance their technical efficiency to achieve maximum production efficiency [TE=1].

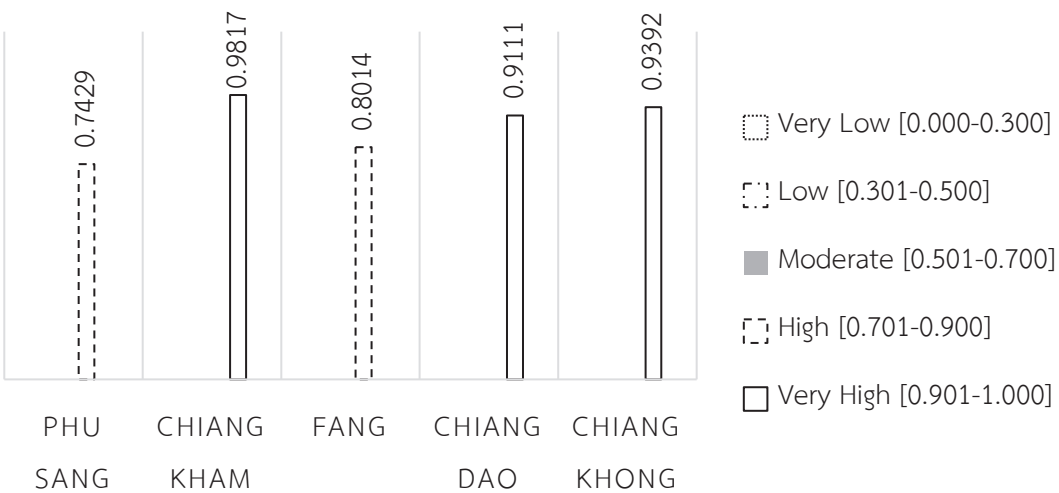

Figure 1 Technical Efficiency Levels of Rubber Plantations in the Five Districts

Analysis of Factors Affecting Technical Inefficiency in Rubber Plantations

The factors contributing to technical inefficiency in rubber plantations were analyzed using the Tobit model. The study revealed that in the upper northern region of Thailand, several variables significantly impact technical inefficiency at the 90% and 95% confidence levels. These variables include the number of training sessions attended, farming experience, employment of tappers, and rainfall amount.

This means that as farmers participate in more training sessions and gain more experience in rubber cultivation, their skills and expertise in rubber planting improve. Additionally, increased rainfall positively impacts rubber tree growth, leading to higher yields. On the other hand, hiring workers for tapping during the harvest season Is a practical choice, but It raises production costs. Moreover, If the hired tappers lack experience, the quantity of latex obtained may decrease.

Table 5 Tobit Model Estimation Results

Factor	Tobit Model	
	Coefficient	Sig.
Constant	0.9197	0.0000
Number of Training Sessions (Z_1)	-0.0015	0.0882*
Experience (Z_2)	-0.0231	0.0929*
Customized Fertilizer Usage (Z_3)	0.0017	0.2296^{ns}
Land Characteristics (Z_4)	-0.0099	0.4602^{ns}
Planting Distance (Z_5)	0.0125	0.3791^{ns}
Hired Tapping (Z_6)	-0.0287	0.0336**
Rainfall (Z_7)	-0.0759	0.0286**
Rubber Tree Diseases (Z_8)	0.0192	0.2287^{ns}
Government Policies (Z_9)	-0.0242	0.1934^{ns}

Source: Derived from calculations

Note: * Statistical significance at the 90% confidence level
** Statistical significance at the 95% confidence level
*** Statistical significance at the 99% confidence level
ns Not statistically significant

Conclusion

This study employed the Stochastic Frontier Analysis (SFA) to evaluate the technical efficiency of rubber cultivation in five key districts of Thailand's upper northern region. The findings revealed that farmers in Chiang Khong (Chiang Rai Province), Chiang Kham (Phayao Province), and Chiang Dao (Chiang Mai Province) demonstrated very high technical efficiency (0.901–1.000), while those in Fang (Chiang Mai Province) and Phu Sang (Phayao Province) exhibited high efficiency (0.701–0.900). These results indicate that, although the rubber farmers in the study areas perform relatively efficiently, none have yet reached their full production potential (TE = 1.00). Thus, improvements in input allocation and management practices remain necessary to enhance productivity. The Tobit regression analysis, conducted at the 90% and 95% confidence levels, identified four variables that significantly influence technical inefficiency: (1) frequency of training sessions, (2) farming experience, (3) employment of tapping labor, and (4) rainfall levels. Specifically, farmers with greater experience and more training opportunities tended to achieve higher efficiency, whereas overreliance on hired tappers was associated with increased inefficiency, likely due to inconsistent tapping quality and higher labor costs. These findings are consistent with several previous studies in the field of

agricultural efficiency. For instance, Abdul-Rahaman (2016) found that education and experience positively affected cotton farmers' technical efficiency in Northern Ghana, emphasizing the role of human capital in improving agricultural performance. Similarly, Pattarakamolsen and Chaovanapoonphol (2018) reported that garlic farmers in Fang District, Chiang Mai, benefited from training and experience in achieving higher production efficiency—a result that aligns closely with the present study's findings for rubber farmers in the same region. Moreover, the present study's observation that rainfall positively affects efficiency emphasizes the critical role of climatic conditions in rubber production. Adequate and well-distributed rainfall supports optimal latex flow, reduces tree stress, and enhances the overall productivity of rubber plantations. Conversely, the inefficiency associated with dependence on hired tappers highlights the importance of effective labor management. Overreliance on external labor can lead to inconsistent tapping practices, increased production costs, and reduced long-term efficiency due to variations in skill levels and limited supervision. From a broader perspective, these findings suggest that the determinants of technical efficiency in rubber production are multifaceted, integrating both human and environmental dimensions. Knowledge acquisition through training, experience-based learning, and adaptive management under changing climatic conditions are essential for achieving optimal performance. Meanwhile, structural challenges related to labor organization and resource utilization continue to constrain farmers from reaching their full productive potential.

Recommendations

1. Production Recommendations: The study indicates that although most districts demonstrate high levels of technical efficiency, some show considerably low efficiency.

This variation is likely attributed to differences in management practices or imbalances in production inputs. To improve efficiency, farmers should adopt better management strategies, including optimizing planting density, regulating fertilizer application, and enhancing their understanding of efficient rubber production techniques.

2. Policy Recommendations: Existing rubber production policies in Thailand have been insufficient in addressing these issues. It is recommended that the government formulate more targeted and supportive policies for rubber farmers. Additionally, adopting best practices from countries with successful rubber sector strategies could enhance the effectiveness of Thailand's policy framework.

References

Abdul-Rahaman, A. (2016). Stochastic frontier analysis (SFA) of technical efficiency: Insights from smallholder cotton farmers in the Northern Region of Ghana. *Global Journal of Agricultural Economics, Extension and Rural Development, 4*(1), 361–367.

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21–37.

Coelli, T. J., Prasada Rao, D. S., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis.* Springer US.

Department of Agriculture. (2023). Agricultural production data of Thailand 2023. *Ministry of Agriculture and Cooperatives.* https://www.doa.go.th [in Thai]

Drinkwater, S., & Harris, R. (1999). Frontier 4.1: A computer program for stochastic frontier production and cost function estimation. *The Economic Journal, 109*(456), F453–F458.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the royal statistical society series a: statistics in society, 120*(3), 253-281.

Krungsri Research. (2024). *Rubber industry outlook 2025–2027.* https://www.krungsri.com/en/research/industry/industry-outlook/agriculture/rubber/io/rubber-2025-2027 [in Thai]

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb–Douglas production functions with composed error. *International Economic Review, 18*(2), 435–444.

Office of Agricultural Economics. (2024). *Agricultural statistics of Thailand 2024.* https://www.oae.go.th [in Thai]

Pattarakamolsen, C., & Chaovanapoonphol, Y. (2018). Technical efficiency of garlic production in Fang District, Chiang Mai Province. *Khon Kaen Agriculture Journal, 46*(2), 359–366. [in Thai]

Phaithun, R. (1998). *Agricultural product marketing* (3rd ed.). Thai Wattana Panich Press. [in Thai]

Rubber Authority of Thailand. (2024). *Rubber statistics report 2024.* https://www.raot.co.th [in Thai]

Songsrirote, N., & Singhapreecha, T. (2007). *Production efficiency analysis in Thai agriculture.* Faculty of Economics. Chulalongkorn University. [in Thai]

Sunsirs. (2024, November 27). *Thailand natural rubber production outlook 2025.* https://www.sunsirs.com/uk/detail_news-23786.html