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Analysis of the Obstacles Faced by Smallholding Farmers in Improving Rubber Production After COVID-19 in South Sumatra Province, Indonesia

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Abstract: The smallholdings sector dominates the rubber plantations in South Sumatra. However, production continued to decline after the COVID-19 pandemic. This study aimed to determine the effect of using seeds, fertilisers, pesticides, the number of plants per hectare, and farmer participation in government technical guidance activities on increasing rubber plantation production. The study also aimed to identify the obstacles faced by rubber smallholders in increasing their production. The study sample consisted of 400 rubber-holding farmers in South Sumatra. Multiple linear regression analysis was employed to assess the impact of these factors on rubber plantation production. Qualitative analysis was also used to analyse the obstacles encountered by smallholder rubber farmers in increasing their rubber plant production. The results showed that the use of seeds, fertilisers, pesticides, and the number of plants per hectare, as well as participation in technical guidance, all simultaneously influenced an increase in rubber plant production. The main obstacles for farmers are the high cost and difficulty of obtaining the recommended seeds, fertilisers and pesticides. Technical guidance from the government is rarely provided, meaning farmers often lack understanding of rubber plantation management, including the ideal number of plants per hectare. Therefore, the government should also ensure that farmers' needs for other types of capital, such as human, physical and social capital, are fulfilled. This research presents one of the first empirical analyses of post-pandemic production constraints in South Sumatra's rubber smallholder sector, providing evidence-based recommendations for policymakers to enhance sustainable plantation management.

Keywords: Smallholding sector, rubber plant production, farmers' obstacles, government role

Introduction

The Role of the Agricultural Sector in the Indonesian Economy

The agricultural sector in Indonesia has continued to grow despite the COVID-19 pandemic. The agricultural sector is dominated by smallholders who are managed by families and have relatively small plots of land. Small farms play a vital role in Indonesia's agricultural sector, but they often face challenges that hinder their full potential, particularly in terms of access. Many small farms

struggle to obtain loans from financial institutions due to a lack of collateral or inadequate credit history. This makes it difficult for them to invest in modern equipment, improved seeds, fertilisers, or agricultural technologies that could improve productivity and crop quality. As a result, they are often trapped in a cycle of poverty, where they are unable to increase their output and income (OECD, 2023). The pandemic has further depressed the small agricultural sector, as large-scale social restrictions have disrupted distribution for agricultural activities and products. Digitalisation and online media are practical efforts in marketing agricultural products, but can only be enjoyed by agricultural actors who understand technology (Sridhar et al., 2023; Salma, 2023).

The pandemic has created inefficiencies in the agricultural sector and the resulting industries (Sridhar et al., 2022). Farmers must feel the impact of the pandemic on the price of agricultural products, which has decreased due to a decline in purchasing power. This is not proportional to the effort and operational costs incurred by farmers in cultivation (Sembiring & Tampubolon, 2024). The social restrictions imposed also create problems, including a labour shortage, limited fertiliser availability, unbalanced supply and demand, and the emergence of post-harvest issues.

During the pandemic period, all economic sectors in Indonesia experienced a decline in growth; however, the agricultural sector's GDP grew at a rate of 2 per cent. However, the growth of the agricultural sector's GDP during the pandemic period did not show a correlation with farmer welfare, as agricultural production costs increased, including those in the rubber plantation sector (Centre of Budget Studies DPR RI, 2021). The study was supported by research conducted by Supriyadi et al. (2023), which states that the agricultural sector has consistently contributed to Indonesia's economy; however, this contribution has not been accompanied by improved welfare for farmers. Farmers are often disadvantaged due to their low incomes. High production costs are linked to the high prices farmers have to pay compared to the prices they receive (Supriyadi et al., 2023).

In fact, the Sustainable Development Goals (SDGs) in the smallholder agriculture sector focus on improving the sustainability, productivity, and well-being of smallholder farmers. Some relevant SDGs include SDG 2 (No Hunger), SDG 1 (No Poverty), and SDG 15 (Ecosystems on Land). Efforts such as training, access to technology, and improved infrastructure can contribute to achieving these SDGs, supporting smallholder farmers in producing food sustainably and enhancing their lives (Nasrullah & Ovitasari, 2021).

Rubber Plantations in Indonesia and Rubber Smallholders in South Sumatra

According to Koltiva (2024), the agricultural sector in Southeast Asian countries, such as Indonesia, Malaysia, and Thailand, is dominated by smallholders, including those in the rubber plantation sector. Rubber plantations are a key source of foreign currency from exports. In Indonesia, the plantation production rate was approximately 3.5 to 4 million tons per year between 2010 and 2018. Following the COVID-19 pandemic, Indonesia's rubber production declined to 3.13 million tons in 2022, followed by 2.9 million tons in 2023 and 2.51 million tons in 2024 (Central Statistics Bureau of Indonesia, 2025). Research conducted by Sembiring and Jongkers (2024) also shows that plantation exports have decreased since the COVID-19 pandemic.

The production of rubber plants, specifically latex, has the potential to be continuously improved, thereby increasing Indonesia's export value (Victor, 2023). Before the COVID-19 pandemic, from 2010 to 2018, rubber exports totalled approximately US$5.5 billion (Commerce Department of Indonesia, 2025). After Covid-19, starting from 2022 to 2024, the decrease in rubber exports was about US$3.65 billion (Central Bureau of Indonesia, 2025).

The potential to increase latex production can begin with efforts to enhance the production of rubber smallholding plantations. The reason is that rubber smallholding plantations dominate the area of rubber plantations in Indonesia, which is 70 per cent. Big companies and government corporations manage the remaining 30 per cent of rubber plantation land. One of the largest rubber smallholding plantations in Indonesia is in South Sumatra Province. According to a report by the Central Bureau of Statistics (2025), in 2018, the total area of rubber smallholding plantations in this province was 1,200,000 hectares and decreased in 2024 (after Covid-19) to 883,000 hectares. The production of latex from rubber smallholdings in South Sumatra Province is about 1,200 kilograms per hectare, while the national average of rubber smallholdings production is about 2,300 kilograms per year. In this province, there are 34,267 smallholder rubber farmers, but their production is only 45 per cent of the total production.

However, overall, with the largest land area, accounting for around 23.5% of the total rubber plantation area in Indonesia, South Sumatra Province remains the largest rubber producer in the country. If the rubber smallholdings sector can be further expanded in production, it will undoubtedly contribute a significantly larger GDP to the Indonesian economy. According to the Central Bureau of Statistics of South Sumatra (2023), the plantation sector in South Sumatra continued to experience growth of around 0.3 to 0.5 per cent during the COVID-19 period.

Rubber has benefits for South Sumatra`s economic growth. The increase in rubber production, especially from the rubber smallholding sector, also has a positive impact on farmers' income and employment, particularly in terms of family labour utilisation. Increasing rubber exports are expected to result in a positive trade balance for Indonesia. For this reason, the government must have a strategy to optimise rubber production, especially from the rubber smallholders sector.

South Sumatra's natural rubber commodity has low competitiveness due to the condition of its plantations and human resources, which are not well managed. Market demand decreases every year, and the role of the South Sumatra government in supporting the natural rubber industry of South Sumatra remains underutilised.

According to the Springfield Centre (2020), the government must implement policies to increase rubber production through the use of quality seeds, controlling leaf fall by providing fertilisers, offering pest control assistance with pesticides, adjusting planting density per hectare, and providing technical guidance. To achieve these goals, it is necessary to include capital assistance and development, where the government will optimise capital assistance. The leading cause of low rubber production is a lack of capital. This lack of capital makes it difficult for farmers to obtain high-quality seeds and other essential inputs, such as fertilisers for plants and pesticides. Low—quality rubber from smallholders' production affects the low price of rubber (Martial et al., 2024).

Research Problem

Latex production from small rubber holdings has the potential to increase Indonesia's exports. South Sumatra Province is a region with the largest area of rubber smallholding plantations in Indonesia, but the production is lower than the national rubber smallholdings production. The area of rubber smallholdings has also decreased after COVID-19. For this reason, it is necessary to identify the factors that influence the production of rubber smallholdings and analyse the obstacles faced by farmers. It is necessary to analyse factors such as the use of seedlings, fertilisers, pesticides, the number of plants, and technical guidance by the government that affect the production of rubber by smallholders in South Sumatra Province. However, there may be other obstacles faced by smallholder rubber farmers that will be analysed.

Research Focus

This research focuses on the production of rubber, measured in kilograms of latex produced per hectare per year by smallholders in South Sumatra Province. Generally, rubber production is likely to be influenced by the type of inputs used (i.e., seedlings, fertilisers, pesticides), the number of rubber plants per hectare and farmers' participation in government technical guidance. This study also examines the potential obstacles faced by smallholder rubber farmers in South Sumatra Province in increasing their rubber production.

Research Aim and Questions

This study investigates why rubber smallholders' production in the South Sumatra Province is generally lower. If the production of rubber smallholders can be increased, it will undoubtedly contribute to national income, specifically increasing the GDP of South Sumatra. Based on the above problem statement, this study aims to answer the following question.

1. To what extent do the variables of seedlings, fertilisers and pesticides, number of rubber trees per hectare, and technical guidance by the government contribute to increasing rubber plant production among smallholders in the South Sumatra Province?
2. What are the obstacles faced by rubber smallholder farmers in increasing their rubber production?

Literature review / Theoretical Overview

In the agricultural sector, factors that influence production are divided into two categories: biological factors, such as seeds, fertilisers, and pesticides, and socio-economic factors, including production costs, prices, and human resources (Arifin et al., 2021). In research on agricultural production, researchers have conducted an analysis of production functions by emphasising several production factors that commonly influence production, namely land (land area), capital, labour (farmers' human resources), and technology (agricultural technology).

The Organisation for Economic Co-operation and Development (OECD) notes that the plantation sector in Indonesia is the country's primary source of income, so it must prioritise the

efficient use of production inputs and invest in human resources and effective management. (OECD, 2022). The agreement of the ITRC (International Tripartite Council, 2023) member countries, namely Indonesia, Thailand, and Malaysia, which are the world's largest rubber producers, states that rubber production is highly dependent on the input of production factors, plant distance, and farmer resources.

According to Koltiva (2024), rubber plantations are found in many areas of Southeast Asia, including Indonesia, Malaysia, and Thailand, which are among the world's largest rubber producers. Rubber contributes to the economic growth of these countries through exports and employment. According to Martial et al. (2023), one of the tropical plants that is a mainstay in plantation commodities is rubber. Latex produced by this plant has long been used as an essential raw material that is processed into goods that are useful for human survival. The main benefit of rubber plants is in the form of natural rubber sap, which is used in making various rubber products. Latex productivity is determined by one of them, namely the management of rubber plant cultivation, which is carried out as a whole, in addition to other factors, including the environment.

According to the Indonesian Rubber Council (2022), farmers should grow a good variety of rubber plants to produce high-quality latex in reasonable quantities. This variety is usually the result of years of research and testing conducted by private and public rubber plant research centres. Using high-quality seeds enables farmers to maximise production potential, improve the efficiency of plantation management and minimise the risk of losses due to pests and diseases. Cultivating rubber plants using random seeds, such as uprooted or pod seeds (derived from seeds or generative propagation), will usually result in low-productivity plants. This will undoubtedly be very detrimental to rubber plant cultivation efforts, and therefore, the use of random seeds should be avoided. Using recommended rubber plant seeds offers numerous benefits, particularly in enhancing productivity and plant resistance (Zulfa et al., 2025). A study found that using local seeds had no impact on rice production compared to using high-quality seeds. Cahyaningtyas et al. (2024) strongly recommend using quality seeds to boost rubber plant production and resilience to unpredictable weather conditions that can reduce production. The analysis utilised descriptive statistics based on data from 2006 to 2019. This study used primary data obtained through the distribution of questionnaires to smallholder rubber farmers. Linear regression was used to analyse the contribution of recommended seedlings to rubber tree production alongside a dummy variable.

After using high-quality seeds, providing fertiliser is crucial for rubber production. The provision of fertilisers for plants is essential for maintaining sustainability, including the use of local fertilisers (Zulfa et al., 2024). The research compares the use of natural fertilisers aimed at promoting agricultural sustainability with high-quality fertilisers. This research uses descriptive analysis. The results show that the use of natural fertilisers can increase agricultural production, but not as optimally as high-quality fertilisers. However, natural fertilisers can help maintain agricultural sustainability because they are readily available at low prices. Research conducted by Martial et al. (2023) using descriptive analysis found that seedlings and fertilisation are the main factors determining income in smallholder rubber plantations, even though these businesses are still managed traditionally. The use of recommended fertilisers, such as NPK Pukalet Rubber Fertiliser or

NPK KOKA, is a good choice for rubber plants because they contain the required macronutrients (N, P, K) and micronutrients. According to Wahyuni et. al (2022), NPK fertilisation of rubber plants is one of the inputs needed in the technical culture of rubber plantations to increase growth and production, but it is less optimal than the use of PB20 fertiliser. Increasing the productivity of rubber plants is crucial, given the promising prospects and development of rubber agribusiness. One of the steps that needs to be taken in increasing the productivity of rubber plants is to apply good cultivation practices (Good Agricultural Practices) of rubber plants, especially in plant maintenance activities. Rubber plant maintenance through fertilisation is one of the essential steps that must be taken to achieve optimal productivity. Lately, the limited availability of fertilisers and the ever-increasing prices have caused fertilisation activities to be delayed. In this research, the use of NPK fertiliser is highly recommended for soil conditions in South Sumatra. This is in line with recommendations from the Sumbawa Rubber Research Institute, South Sumatra. The analysis in this study uses linear regression to examine the contribution of recommended fertiliser use to rubber tree production with a dummy variable.

The use of pesticides in rubber plantations can help solve problems of pests and diseases, which can hinder and even kill the plants (Okubo-Kurihara et al., 2024; Arsi et al., 2022). Weed control must follow the recommended rules. Errors in control can reduce latex production. Control can be achieved through mechanical, technical, biological, preventive, chemical, and integrated control methods. Currently, chemical weed control is the most effective alternative for controlling weeds in rubber plantations in Indonesia. The use of pesticides for rubber plants in Indonesia is a herbicide with the active ingredient ammonium glufosinate + indaziflam 257 g/l, with a dose of 2 l/ha (514 g ba ha-1), which can control the growth of weeds (Ageratum conyzoides, Borreria alata, Asystasia intrusa, Synedrella nodiflora, Axonopus compressus) and other weeds in rubber plantations. For rubber plants, keep away the most common diseases from the plants, such as fungus, because it can kill the plants, as well as areas of tapping disease, root disease and leaf disease. Soil and nature are essential determinants in the latex production. In this study, pesticide use was measured using dummy variables for herbicides recommended by the Sembawa Rubber Research Institute. The analysis in this study uses linear regression to examine the contribution of recommended fertiliser use to rubber tree production with a dummy variable.

The production and quality of rubber plants are also greatly influenced by planting distance. Proper spacing allows plants to get enough sunlight, water and nutrients, thereby increasing growth and yield. Plant spacing that is too tight can cause competition between plants, while spacing that is too wide can reduce land use efficiency. Research conducted by Tahnh & Nguyen (2022) using experimental methods on rubber clone types and plant density showed that tall rubber trees with smaller circumferences can be planted more densely on land than rubber trees with larger circumferences. Planting distance affects rubber tree yield. According to Statistics Indonesia (2023), in South Sumatra Province, the ideal number of rubber trees per hectare is 500 trees with a spacing of 5x4 meters. A reasonable rubber planting distance can provide benefits, namely: ensuring that each rubber tree gets enough space to grow optimally, absorb water and nutrients, and produce high-quality and abundant rubber latex. This is the main key to a maximum and profitable rubber

harvest. In this study, planting distance was analysed using linear regression to analyse the effect of the recommended planting distance variable on rubber tree production using a dummy variable.

The mistake that farmers often make is that they do not understand the importance of using quality seeds, fertilisation, pesticides and land management, which play a vital role in obtaining maximum production results. This may occur due to limited capital. Various studies related to the quality of rubber seedlings, the use of fertilisers and pesticides, and the number of plants that need to be replanted will be managed by human resources, specifically farmers, through an understanding of the novelty of rubber plant cultivation. The government can do this by increasing training. It is necessary to have human resources that encourage agricultural excellence (Sridhar et al., 2023; Salma, 2023). Research conducted by Arowosegbe et al. (2024) using survey analysis shows that agricultural extension officers play a critical role in transforming the supply chain by bridging the gap between research, innovation, and agricultural practices in the field. This article discusses how agricultural extension officers in Nigeria contribute to increasing productivity, promoting hunger, and encouraging the spread of innovative technologies in the agricultural sector. This study focuses on the influence of farmer participation in technical guidance provided by the government to enhance rubber plant production. The indicator is the frequency of following the technical guidance.

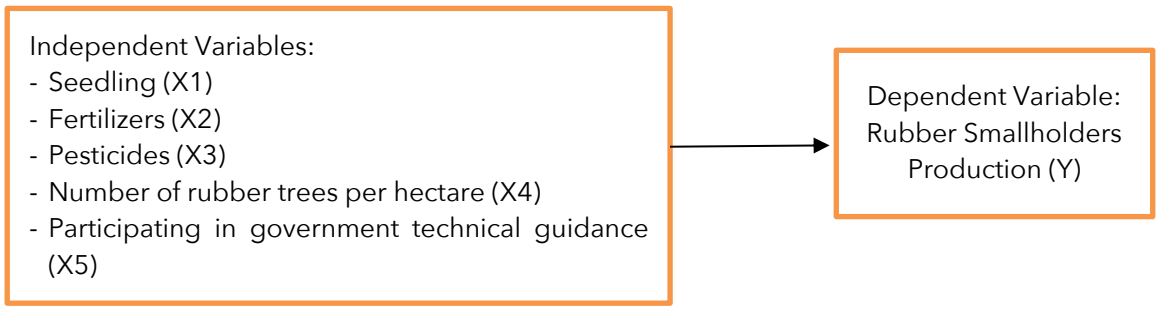
The rapid changes in the pattern of social communication technology were evident and felt during the global spread of the COVID-19 outbreak. This development gives a new colour to the political, economic, and social aspects of society. Technology is important because it is indispensable in all aspects of life and can support the effectiveness and efficiency of human ability to interact and work. According to Cheng et al. (2024), digitisation skills are needed to (1) utilise digital resources to obtain information about technology, knowledge, policies, and markets; (2) understand financial information and obtain credit through online platforms; and (3) improve daily life by using devices such as smartphones. This underscores the pervasive influence of digital thinking across the domains of production and farmers' lives.

Research conducted by Danapriatna et al. (2023) showed that the higher the role of agricultural extension workers, the higher their performance. Extension also plays a vital role in marketing, providing technological information, teaching, training, guidance, consulting, encouragement, and services to facilitate the availability of production inputs, as well as serving as a medium for interaction between farmers (Sulandjari et al., 2020).

The framework for solving the problems in this study begins with analysing the factors that affect the production of rubber plants, namely the use of seeds, fertilizers, pesticides, the number of rubber trees per hectare, and technical guidance by the government. Following this, an analysis is conducted to examine the problems faced by smallholder rubber farmers due to the use of these factors and other constraints, to provide a policy basis to increase the production of smallholder rubber plantations. The conceptual framework of thought in this research can be seen in Figure 1 below.

Figure 1

Conceptual Framework



Research Methodology

General Background

This section discusses how to determine the sample in this study, research instruments and procedures, and data analysis. The focus of the study is on rubber smallholder farmers in South Sumatra, which is divided into two regencies: Banyuasin Regency and Muara Enim Regency. The reason for choosing these regencies is that they have the largest population of rubber smallholder plantations in South Sumatra Province. This study uses quantitative analysis with multiple regression analysis to identify the effect of the use of recommended rubber seeds (namely BR 1 and RRII), recommended fertilisers (namely N, P, K), recommended pesticides (namely types of herbicides), the number of rubber trees per hectare and participation in technical guidance by the government that contribute to rubber plant production. Descriptive analysis is also used in the study to analyse the obstacles faced by farmers to increase production in South Sumatra Province.

Participants / Sample

The respondents in this study were smallholder rubber farmers in South Sumatra Province. According to a report by the Central Statistics Bureau of Indonesia (2025), the population of rubber smallholders in the South Sumatra Province is 34,827 farmers. By using the Slovin formula at a 1% error rate, the number of respondents used as samples in the study was 400. The sample was taken using random sampling. The respondents were homogeneous, so the distribution of the questionnaire can be done randomly (Adeoye, 2024; Dubey & Kothari, 2022). The questionnaire was distributed to areas with the most significant number of rubber smallholder farmers in South Sumatra, namely Banyuasin (200 respondents) and Muara Enim districts (200 respondents).

Instrument and Procedures

Data was collected from respondents using a structured questionnaire instrument from those sampled through random sampling, as shown in Table 1 below.

Table 1

Quistionare Instrument

A. RUBBER SMALLHOLDER PRODUCTION	
Variables	**Description**
Seeds (X1)	1. Type of rubber seeds use following BRI or RRII: a. Yesb. No 2. If yes, describe your reasons 3. If no, a) Describe your reasons b) How do you get seeds you used
Ferilizers (X2)	4. Type of rubber seeds use following NPK: a. Yes b. No 5. If yes, describe your reasons 6. If no, a) Describe your reasons b) How do you get seeds you used
Pesticides (X3)	7. Type of rubber seeds use following herbicides: a. Yes b. No 8. If yes, describe your reasons 9. If no, a) Describe your reasons b) How do you get seeds you used
Number of rubber trees per hectare (X4)	10. Number of rubber trees per hectare less than or equal to 500 rubber trees per hectare: a. Yes b. No
Participating in government technical guidance (X5)	11. How frequent your participation in one year?
B. Miscellany	
12. What constraints are faced in improving the production of rubber plantation? 13. Why does it happen? 14. Do you think the rubber farming still a good prospect? 15. Are technical guidance activities provide benefit to you as a rubber farmer's? 16. How far from your living place to centre of Banyuasin Regency (Kilometer) 17. Is there any involvement from the government (through KUD) toward the capital aid (capital loan, seeds subsidy, fertilizers subsidy, etc) for rubber smallholders in this area? a. Yes b. No 13. If yes, do you think the loan is sufficient? 14. Are the requirements of KUD affordable by you?	

Data Analysis

The data was analysed using Statistical Package for the Social Sciences (SPSS), i.e., to analyse the determinants of rubber smallholders' production such as seedlings (X1), fertilisers (X2), pesticides (X3), number of rubber trees per hectare (X4) and technical guidance by government (X5).

The model for rubber smallholders' production is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

The Equation is used to identify the influence of variables of seeds (X1), fertilisers (X2), pesticides (X3), Number of rubber trees per hectare (X4) and participating in government technical guidance (X5) on the rubber smallholders' production (Y). Variables X1, X2, X3 and X4 are nominal-scale variables. Another analysis is descriptive analysis, which is used to analyse another obstacle faced by farmers to improve production.

The limitations of the variables are as follows:

1. Rubber smallholders' production (Y) is the total latex produced per kilogram per year per hectare.
2. Seedlings (X1) is a dummy variable where:

   1 = Using BR1 or RRII
   0 = if otherwise
3. Fertilisers (X2) is a dummy variable where:

   1 = Using NPK

   0 = if otherwise
4. Pesticides (X3) is a dummy variable where:

   1 = Using herbicide

   0 = if otherwise
5. Number of rubber trees per hectare (X4) is the dummy variable where:

   1 = less than or equal to 500 rubber trees per hectare
   0 = more than 500 rubber trees per hectare
6. Participating in government technical guidance (X5) refers to the number of times the farmer has participated.

The classic assumption test is used to assess the validity of the regression model employed in this study and is a crucial step in the regression process. Violation of classical assumptions indicates that the effectiveness of the regression model obtained is less valid. The classic assumption test is carried out through four stages: the normality test, the multicollinearity test, and the heteroscedasticity test (Ghozali, 2021).

The normality test is used to determine whether the confounding or residual variables in the regression model have a normal distribution. A good regression model has a normal distribution or is close to normal, making it feasible and allowing for statistical testing. The basis for decision making can be based on probability (Asymptotic Significance), namely:

a. If the probability > 0.05, then the distribution of the population is expected.

b. If the probability < 0.05, then the population is not normally distributed.

The multicollinearity test is a test conducted to detect the presence of a linear relationship between independent variables in a multiple regression model. The aim is to ensure that the independent variables are not closely related to each other, as a high correlation between independent variables can lead to problems in interpreting regression results. (Ghozali, 2021). Multicollinearity testing can be done with the tolerance value and the variance inflation factor (VIF). A low tolerance value (generally below 0.10) indicates the presence of multicollinearity. Variance Inflation Factor (VIF): Is the opposite of tolerance. A high VIF (generally above 10) indicates the presence of multicollinearity.

The heteroscedasticity test aims to test whether there is a variance inequality in the residuals from one observation to another observation in the regression model. If the variance of the residuals of one observation relative to other observations is constant, it is called heteroscedasticity. A good regression model is homoscedastic, meaning it does not exhibit heteroscedasticity (Ghozali, 2021). The occurrence of conditions of heteroscedasticity will result in the coefficient not being absolute; for example, there will be less or more than it should be. The basis for decision-making is as follows:

a. If the p-value≥ 0.05, it means that there is no heteroscedasticity problem.

b. If the p-value ≤ 0.05, it means that there is a

To prove the hypothesis, the following steps were taken: test the hypothesis with the t-test. And the F test. In this research, the t-test and F-test are used to determine the effect of each independent variable on the dependent variable when both are carried out simultaneously.

Results

This section discusses the production of rubber, measured in kilograms of latex produced per hectare per year by smallholders in South Sumatra Province. Generally, rubber production is likely to be influenced by the type of inputs used (i.e., seedlings, fertilisers, pesticides), the number of rubber trees per hectare and their participation in technical guidance by the government.

The results of this study showed that the majority of latex produced by smallholder farmers (74.1 per cent) produces not more than 1,200 kg of rubber per hectare per year. Approximately 25.9 per cent of the farmers achieve a yield of around 2,300 kg per hectare per year. It was found that the majority of the latex production by smallholder farmers in South Sumatra Province is less than 2,300 kg per hectare per year.

Statistical testing of this study begins with a regression analysis test, followed by a normality test. The basis for decision-making is the use of probability values. In this study, the probability value is greater than, indicating that the research model is normally distributed and feasible for statistical testing.

This study also conducted tests for multicollinearity problems using the tolerance test and the VIF test. A good tolerance and VIF (Variance Inflation Factor) value in regression analysis is tolerance

> 0.10 and VIF < 10. If the tolerance value is less than 0.10 or the VIF value exceeds 10, this indicates a multicollinearity problem. The results of tolerance and VIF values indicate that the variables used in the study do not exhibit multicollinearity problems.

The heteroscedasticity test in the study used the chi-square test. The Chi-square (χ^2) test is a statistical test used to test the difference between the observed frequency and the expected frequency in data, usually categorical data. The Chi-Squared test is 0.1493, so it is greater than the alpha value (0.05), namely (0.1493> 0.05). If it exceeds the alpha value (0.05), it means that the data is free from heteroscedasticity problems.

Based on the classical assumption test, it can be stated that the model in this study is suitable for the regression process. The regression model for the production of smallholder rubber plantations is presented in Table 2.

Table 2

Regression Model for Rubber Smallholders' Production in South Sumatra Province

Model	Non-standardized Coefficients		Standardize Coefficients	t- statistic	P-value
	B	Std. Error			
Constant	- 70.479	86.364		-.816	.415
Seeds (X1)	428.778	39.933	.207	10.737	.000
Fertilizers (X2)	409.125	37.640	.211	10.869	.000
Pesticides (X3)	209.767	34.165	.107	6.140	.000
Number trees per hectare (X4)	1.462	.050	.634	29.007	.000
Participation in technical guidance (X5)	97.541	18.114	.116	.116	.000

Notes: Dependent Variable.
Y = Rubber Smallholders Production in kilograms/year per hectare.
Adjusted R^2 = 0.879

From Table 1, the equation of rubber plantation production in South Sumatra Province can be written as follows:

$$Y = -70.479 + 428.778X_1 + 409.125X_2 + 209.767X_3 + 1.462X_4 + 97.541X_5$$

With α = 5%, this implies that each variable has a significant influence on rubber smallholders' production in South Sumatra Province. The variables of seeds (X1), fertilisers (X2), pesticides (X3), number of trees per hectare (X4) and participation in technical guidance by the government show a significant influence on the rubber smallholders' production (Y). From the data processing, an adjusted R^2 value of 0.879 was obtained, indicating that all independent variables studied explained 87.9 per cent of the accuracy of rubber smallholders' production (Y), with the remaining 12.1 per

cent attributed to other variables not accounted for in the model. In addition, the results of the F test showed that the F-statistic (i.e. 447.67) was greater than the critical value of F (i.e. 2.87) which means that the regression coefficients of the recommended seedlings BR 1 or RRII (X1), recommended fertilizers using NPK (X2), recommended pesticides using herbicide (X3), number of rubber trees per hectare less than or equal 500 rubber trees (X4) and participating in government technical guidance (X5) in the reference population were not all zero (has a significant impact on rubber plant production).

From the results of this study, it is also known that the majority of smallholder rubber farmers (74.1%) face the main problems of obtaining recommended seedlings, fertilisers, and pesticides due to capital constraints (high prices) and difficulties in accessing them. In addition, they rarely attend training because the long distance constrains them, so their understanding of rubber plant management, such as planting distance, is minimal. Farmers who follow rubber plant management using recommended seeds, fertilisers, and pesticides, and who often attend technical guidance activities, obtain production results that are in accordance with national production, namely 2,300 kg per hectare per year.

Discussion

The rubber smallholders in South Sumatra Province generally live on subsistence income, and many of them are impoverished, so this study was carried out to analyse factors influencing smallholders' rubber production in this area and propose ways to improve their production. Raising rubber smallholder production will pave the way for Indonesia to expand its natural rubber exports. Smallholders produce a large percentage of the province's natural rubber. Besides ensuring that Indonesia has a competitive advantage in natural rubber production, strategies to increase rubber production among smallholders also support the three pillars (growth, equity, and stability) of economic development in Indonesia. Any increase in smallholder rubber production will contribute to economic growth and poverty alleviation.

Factors that influence the increase in rubber plant production, namely the use of recommended seeds, the use of recommended fertilisers, the use of recommended pesticides, the number of rubber trees per hectare and participation in government technical guidance, have been proven to have a significant effect on increasing rubber plant production. This study supports several previous studies conducted by the Indonesia Rubber Council (2022) and Cahyaningthyas (2023), which explain that the use of quality seeds affects rubber plant production. The recommended seeds for rubber plants in Indonesia are Clone BR1 and RRII.

The results of this study also prove that the use of fertilisers has a significant effect on the production of rubber plants. The results of this study support the research conducted by Martial et.al. (2023), Wahyuni et al. (2022) and Zulfa et al. (2022), which informs that the use of recommended fertilisers in this case, N, P, K, has a significant effect on fertilising plants and providing nutrients to accelerate the production process in rubber plants. The use of pesticides, in this case herbicides, is highly recommended in overcoming weeds so that rubber plants can thrive.

The use of pesticides in the study had a significant effect on rubber plant production, which was supported by research conducted by Arsi et al. (2022) and Okubo-Kurihara et al. (2024). The use of pesticides for rubber plants in Indonesia is a herbicide with the active ingredient ammonium glufosinate + indaziflam 257 g/l, with a dose of 2 l/ha (514 g ba ha-1), which can control the growth of weeds (Ageratum conyzoides, Borreria alata, Asystasia intrusa, Synedrella nodiflora, Axonopus compressus) and other weeds in rubber plantations. For rubber plants, keep away the most common diseases from the plants, such as fungus, because it can kill the plant, as well as areas of tapping disease, root disease and leaf disease. Soil and nature are essential determinants in the latex production.

The next factor that influences the increase in rubber plant production is the understanding of rubber plantation land management technology, namely, the ideal plant distance. Based on the results of this study, the ideal plant distance has a significant effect on rubber plant production. This study supports research conducted by Thanh and Nguyen (2022). By looking at the natural conditions in South Sumatra, the ideal number of rubber trees per hectare is 500 trees with a planting distance of 5 x 4 meters. This means that the addition of rubber trees will only increase latex production by a maximum of 500 rubber trees per hectare, and then each additional tree will reduce latex production.

Understanding efforts to increase rubber plant yields is crucial for enhancing farmer resource skills (Cheng et al., 2024; Salma, 2023; Sridhar, 2023). Farmers can acquire skills and gain an understanding of rubber plant management through government-organised training. In this study, government technical guidance showed a significant influence on rubber plant production.

However, the obstacle is that the majority of farmers (74.1%) do not use recommended seeds, fertilisers, and pesticides because they are expensive and difficult to obtain. Farmers do not follow agricultural management because they are constrained by capital. In general, the primary constraint for smallholders is capital (Ahmad, 2025). The results of this study are also supported by research conducted by Nadhar et al. (2024), which showed that there is a positive and significant relationship between production costs and agricultural production. The greater the capital owned for agricultural production, the higher the quality and quantity of crops, and conversely, the smaller the capital owned for production, the lower the quality and quantity of crops. Larger plantation companies have stronger financial capabilities to buy land in strategic and easily accessible locations. They are also able to invest funds to build adequate road or transportation infrastructure.

Based on direct observation, the procurement of seeds, fertilisers, and pesticides is carried out by agencies that act as intermediaries, providing their services in exchange for compensation in the form of wages, thereby increasing the price. In Indonesia, they are known as “Calo”. The government should immediately build partnerships with smallholder rubber farmers to prevent the manipulation of prices by these “Calo”. To overcome the Calo, providing technical guidance in digital skills enables the timely and accurate collection of information, reduces information search costs, and effectively mitigates information asymmetry and financing constraints. This facilitates rapid entrepreneurial activities after identifying business opportunities (Leng, 2022). In addition, farmers

can also engage in online procurement of agricultural materials and conduct online marketing of agricultural products through the Internet (Li et al., 2021).

The participation of smallholder rubber farmers in government technical guidance is also minimal due to information constraints and long distances. This is evident from the study results, where 85% of farmers stated that they were unaware of the schedule and location of the technical guidance, even though they acknowledged not attending the training due to the long distance. Meanwhile, 15% of farmers attended the technical guidance, but not on a routine basis, for the same reason.

Conclusions and Implications

The results of this study conclude:

1. Use of recommended seeds, namely BR1 and RRII, use of recommended fertilizers (N, P, K), Use of recommended pesticides, namely herbicides, number of rubber trees per hectare from the results of this study, it can be concluded that the decline in rubber plant production in people's rubber plantations after Covid-19 was influenced by the majority of farmers (74.1%) not using recommended seeds, recommended fertilizers, recommended pesticides, ideal number of rubber trees per hectare and farmer participation in technical guidance has a significant effect on increasing rubber plant production.

2. The problems of farmers in using recommended seeds, recommended fertilisers, and recommended seeds are the limited capital and long distances. The obstacles faced by farmers in using recommended seedlings, fertilisers, and pesticides are issues of access and cost. The government should ensure that farmers have better access to these inputs by making them available in even the most remote locations. The government should also introduce easy repayment schemes with lower interest rates on borrowings and increase the subsidies for vital agricultural inputs (e.g., seedlings, fertilisers and pesticides) so that it is more affordable for the farmers to purchase them.

The government can play a supporting role by extending microcredit schemes to rubber farmers, enabling them to venture into cottage industries (e.g., chip production, pickles, jam, etc.). This allows farmers to use their agricultural products more profitably. Additionally, the government can assist farmers in marketing the products of these cottage industries.

Based on the research findings, the government should also ensure that the needs of farmers for other types of capital are fulfilled. This include human capital with training, physical capital (access to infrastructure such as roads, communication systems, access to rubber and other agricultural commodity markets and rubber processing facilities) and social capital (access to institutional support provided by the governmental agencies for growing rubber; access to technology, R&D facilities, and training in tapping and rubber processing; access to extension services, self-help groups, access to social networking, and information).

Suggestions for Future Research

Further research is needed to investigate the role of other factors that affect smallholder rubber production. These other factors include environmental variables, institutional factors, technology and cultivation techniques. The inclusion of these variables will provide a more comprehensive understanding of how best to improve the production of rubber smallholders. If Indonesia does not act now, it may lose its competitive advantage in natural rubber. Just as in the cases of Malaysia and Thailand, wages in Indonesia are expected to rise, and the `pull` from more lucrative sectors will lead to a labour shortage in the agricultural sector as the economy progresses. Suppose there is no increase in rubber smallholder production to offset these trends. In that case, the low-cost advantage of Indonesia's rubber smallholders will be wiped out, and this will harm the country's natural rubber sector.

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Conflict of Interest

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