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Analysis of the Influence of Productivity and Efficiency of the Plantation Sector on the Island of Sumatra with DEA and MPI Approaches

Dian Wahyuni[1*], Hadi Suriono[2], Saleh Malawat[3], Heni Subagiharti[4], Rossy Pratiwi Sihombing[5]

[1,2,3,4]Faculty of Economics, University of Asahan 21216, Kisaran North Sumatera, Indonesia.
[5]Faculty of Economics, Medan State University 20221, Medan North Sumatera, Indonesia.

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Abstract. This research analyzes the levels of efficiency and productivity within the plantation sector across 8 provinces in Sumatra during the period of 2016-2021. This analysis employs the Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI) methodologies. The utilized input variables encompass land area, quantity of fertilizer, and the agricultural workforce within the plantation sector. As for the output variables, they encompass the quantities of palm oil production, coconut production, coffee production, and rubber production. The research findings reveal fluctuations in the efficiency and productivity levels of the Sumatra plantation sector year by year. The efficiency levels exhibit an upward trend, while the productivity levels on average display a decrease, primarily attributable to a decline in technological change (TECHCH). Furthermore, an analysis conducted during the Covid-19 pandemic period indicates that the pandemic has notably impacted the efficiency levels within the plantation sector. However, in terms of productivity levels, Covid-19's influence appears to be insubstantial. Delving deeper, the findings from the potential improvement analysis reveal that the foremost sources of inefficiency stem from the output variables, particularly the coffee production quantity, followed by the palm oil production quantity. In light of these research outcomes, recommendations are extended to pertinent stakeholders. It is advised to concentrate efforts on the development of the plantation sector, encompassing policy initiatives, stimuli, and the incorporation of technology within plantation activities.

1. INTRODUCTION

Sector The plantation sector in Indonesia, especially on the island of Sumatra, still faces various problems, among masalah the main problems that efisiensi the technical efficiency perkebunan kelapa of oil palm plantationsin Indonesia is still far from optimal(1). Almost half of the total pendudukIndonesian population still lives in rural areas, which tentunya will certainly depend dirion sektor the plantation sector as sumber their main source of income mereka(2). That produktivitas perkebunansmallholder plantation productivity remains relatively low is a challenge that needs to be addressed, given pertumbuhan pendudukIndonesia's growing population, while the opportunities yang generated by sektor-sektorother sectors are not growing dengan rapidly(3).

Based on BPS data tahunin 2021, the largest production komoditas of plantation commodities, including kelapa oil palm, rubber, coconut, coffee and areca nut, terbesar is on the island of Sumatra. About 53 percent of the national oil production is produced on the island of Sumatra, which is 24.4 million tons in 2021. Provincial rubber production on the island of Sumatra is 2.2 million tons or 70 percent nationally, coconut 722 thousand tons or 25 percent, and coffee 374 thousand tons or 48 percent, but the production of the plantation sector is inversely proportional to other sectors. Therefore, there is a need for Policy and efficiency related to this problem.

There are two main factors that cause differences in productivity. First, biological constraints, such as varietal differences, attacks on plant disturbing organisms, soil fertility, and others.Second, socio-economic constraints, such as differences in the amount of production costs, the level of education and knowledge of farmers, and so on(4). More than half of the total coffee plantations in each province show low productivity levels. Educational variables proved to be significantly influential in improving both productivity and technical efficiency in the coffee plantation business(5).

The results showed that of the nine technical inefficiency variables tested, there are seven variables that affect technical inefficiency. The variables tersebut are education, age,sistem planting system, kualitas seed quality, pests, counseling, and petaniplasma farmers(6). The results of the analysis showed that faktor ketidakefisienan the technical inefficiency factor was caused by the age of the farmers and the number anggota rumah of household members involved in agriculture business the oil palm farming business palm oil (7)

*Corresponding author.
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Table 1. Production Results of the Oil Palm Plantation SectorSawit on The Island of Sumatra In 2019-2021.

No.	Province	Hasil output/ton		
		2019	2020	2021
1.	Aceh	1,133,347	1,134,606	1,167,337
2.	North Sumatra	5,647,313	5,776,781	5,928,612
3.	West Sumatra	1,253,394	1,312,253	1,350,125
4.	Riau	9.513.208	9.984.315	10.270.149
5.	Riau Island	22,788	20,020	20,631
6.	Jambi	2,884,406	3,022,565	3,109,205
7.	South Sumatra	4,049,156	4,267,023	4,388,731
8.	Island Bangka Belitung	815,667	843,047	868,462
9.	Bengkulu	1,032,056	1,063,404	1,093,456
10.	Lampung	414.206	384.948	395.967

Source: Ditjenbun Directorate General of Agriculture.

As an example of one type of plantation sector Commodity, namely oil palm, the data above shows the results of oil palm production on the island of Sumatra from 2019-2021, only one province experienced a decline in production each year, namely Riau Islands province. The largest production is produced by Riau Province in 2021 as much as 10,270,149/ton, but the problem is in the prolonged disruption of plantation business that can inhibit production on the island of Sumatra in the coming year. Even the problems that arise can discourage investors from investing in plantation businesses because there is no legal certainty on a land.

The purpose of this study is to obtain a complete picture and analyze the plantation sector in 10 provinces on the island of Sumatra on the level of productivity and efficiency, as well as finding the potential improvement of the plantation sector on the island of Sumatra in order to contribute to the national economy.

Based on the description above, research on the analysis of the effect of productivity and efficiency of the plantation sector on the island of Sumatra with the DEA and MPI approach, it is important to understand the potential of the plantation sector and can support the economy on the island of Sumatra and even nationally and internationally. For that can be identified problems in this study are:

1. How does the productivity sektor of the plantation sector in Sumatra affect?
2. How does the efficiency of the plantation sector in Sumatra affect?

Based on the law of the Republic of Indonesia number 18 of 2004 on plantations states that plantations are all activities that cultivate certain crops on land or other growing media in the appropriate ecosystem and process and market goods and services of these crops with the help of Science and technology, capital, and management to realize for business actors erkebunan and Community(8). Konsep efisiensi dapat dibedakan menjadi tiga, yaitu: (1) efisiensi teknis (*technical efficiency*), (2) efisiensi harga (*price efficiency*), dan (3) efisiensi ekonomis (*economic efficiency*)(9). Increased productivity often involves increasing efficiency, optimizing resource allocation, implementing new technologies, and investing in Human Resources(10).

Such a partnership is still not in favor of the farmers are farmers Arfak Tribe in Manokwari West Papua. Many farmers contract their plantations due to the lack of education level of farmers in the management of oil palm plantations, because there has not been a partnership between smallholder farmers and large plantation companies(11). Low level of efficiency and quality of yield are the main problems in plantations. This is because there is no ideal Plantation Management in the use of advanced technology, especially the use of superior seeds, manure, irritation, infection(12).

The area of large state plantations tends to decrease, then the productivity of smallholder plantations is very low compared to large private and State Plantations. If the productivity of smallholders estate can be increased at least equal to the productivity of large private plantations, the production of oil palm will increase by 16,273,170 tons(13). The need for capital assistance in farming by the local government so that farmers in the study area can buy production inputs optimally(14).

The results of technical efficiency analysis, factors of production production of land area, seed, urea fertilizer, ZA fertilizer, NPK fertilizer, pesticides and labor are not technically efficient with a production elasticity value below one(15). Increased plantation productivity can help reduce pressure on new forests and improve resource efficiency. In addition, increasing the efficiency and productivity of the plantation sector can contribute to the country's economic growth(16). Penerapan *Data Envelopment Analysis* (DEA) dan *Grey Model* untuk evaluasi produktivitas industri agroforestri Vietnam. The results of this study explain that some companies can achieve optimum efficiency, while other companies are less efficient(17).

This study is different from previous studies because it uses the approach of DEA and MPI analysis methods, which then the number of samples taken is 10 provinces on the island of Sumatra from 2018-2022 and the addition of indicators of input variables and output variables. Strategic issues in accordance with the topic of this study is the efficiency of the value chain of agricultural products, plantations, livestock in order to face the technology of resilience and food independence in the future.

Problem solving this study uses a quantitative research approach with *a non-parametric approach description.* The Data used is secondary data, with metode data *time series data method* from tahun2018-2022. analisis yang digunakanThe first analysis method pertama isatechnical efficiency analysis using menggunakan *Data Envelopment Analysis* (DEA) which is metode *a non parametric method*,analisis yang the second analysis is *Malmquist Index Productivity* (MPI). To overcome this problem , it is necessary dilakukan upaya to integrate all variabel yang related variables in it. For more details kerangka pemikiran of the research framework as follows:

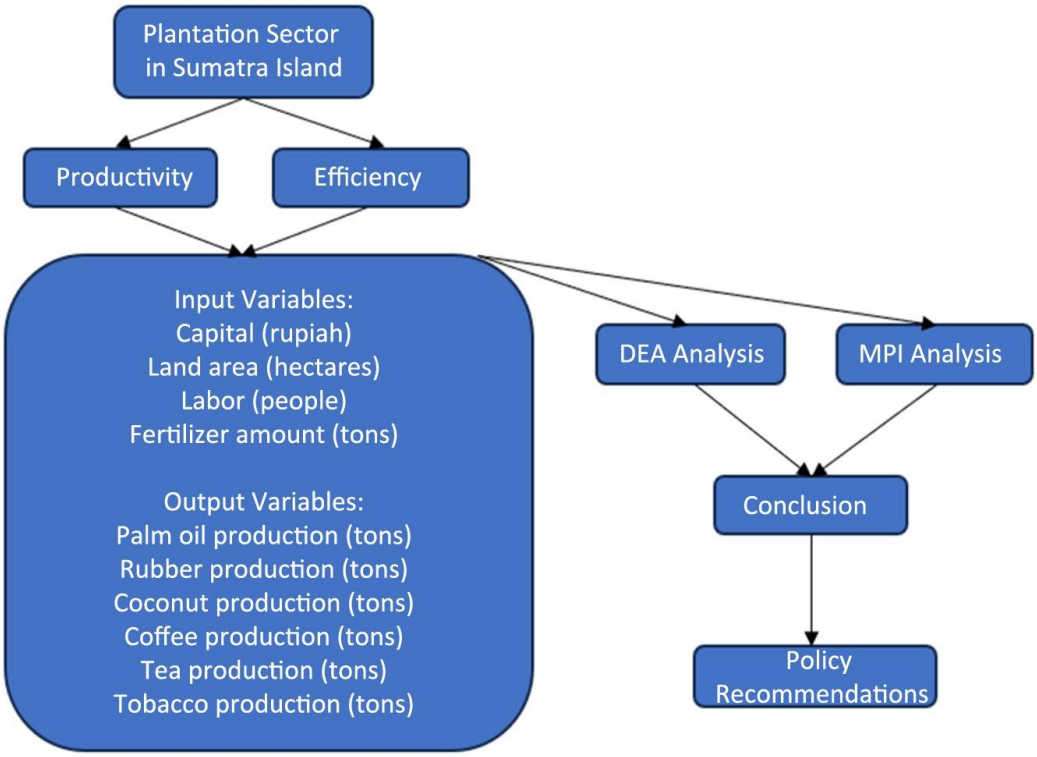

Figure 1. Kerangka Conceptual Framework.

2. METHODOLOGY

2.1. Data Source

The time of the study was carried out from the beginning of 2024 to the end of 2024. The location of this research is all 10 provinces on the island of Sumatra, through the Ministry of Agriculture Directorate General of plantations on https://ditjenbun.pertanian.go.id / and the National Statistics Agency on https://www.bps.go.id/id.

The Data used in this study is secondary data, namely in the form *of time series data* for 5 years on the island of Sumatra from the period 2018-2022. Data collection methods used are *library research*(Library) and documentation techniques, which come from publications such as journals, books, or official documents such as government reports or company data, and others (18). Furthermore, this study uses input variables and output variables in order to measure the level of productivity and efficiency of the plantation sector throughout the province on the island of Sumatra as follows:

Table 2. Variable Research Variables.

Variables	Data source
Input	
Capital Input (rupiah)	Central Bureau of Statistics and Directorate General of plantation
Luas land area (hectares)	Directorate General
of plantation labor (People)	Directorate General of Plantation
amount of fertilizer (tons)	Directorate General of Plantation
Output	
Total oil palm production (tons)	Central Bureau of Statistics
Total rubber production (tons)	Central Bureau of Statistics
Total coconut production (tons)	Central Bureau of Statistics
Total coffee production (tons)	Central Agency for Statistics
Total tea production (tons)	Central Agency for Statistics
Total tobacco production (tons)	Central Agency for Statistics

Source: Ditjenbun Directorate General of Agriculture.

The population in this study is all 10 provinces on the island of Sumatra. Furthermore , the sample used in penelitian this study is *judgment Sampling*. *Judgment Sampling method* or biasa disebutalso called dengan *Purposive Sample* is pengambilandata collection on the basis of skill strategies or pertimbangan personal considerations alone(19). Therefore itu, this study ini will focus on 10 provinces adain the Sumatra island region, namely Aceh, North Sumatra, Riau, KepulauanRiau Islands, West Sumatra, Jambi, South Sumatra, Bengkulu, KepulauanBangka Belitung Islands, and Lampung.

The first method of analysis used pertama is atechnical efficiency teknis analysis using Data Envelopment Analysis (DEA) which is metodea non parametric method to measure the effectiveness of a dynamic unit (work unit) that bertanggung is responsible for utilizing various contributions to obtain the results specified specifically in this study ini is sektorthe Plantation Sector(20). The equation for measuring efficiency can be written as follows:

$$\textit{Efficiency of DMU} = \frac{\sum_{k=1}^{p} \mu_k \, y_{k0}}{\sum_{i-1}^{m} v_i \, x_{i0}} \quad (1)$$

Description:

m = different inputs

p = output-output yang berbeda

xi = the number of inputs I generated by the DMU
yk = number of outputs K produced by the DMU

Efficiency scores on DEA range between 0 and 1 or 100%. Where, *the Decision Making Unit* (DMU) with a score of 100% indicates that the DMU is efficient, and the lower the DMU score, the more efficient the DMU.

Analisis yang The second analysis is *the Malmquist productivity Index*(MPI) used to measure changes in innovation(21). The indeks kuantitasMalmquist input quantity index is used for unit production units at the time of observation t and t + 1, for teknologi reference technology at the period k, k = t and t + 1, and measures the change kuantitasin the input quantity observed between the time t and t + 1, where:

$$MI_k\,(y_k, x_t, x_{t+1}) = \frac{E_k^I\,(y_k, x_t)}{E_k^I\,(y_k, x_{t+1})}\,,\ k = t,\ t+1 \quad (2)$$

Then, for indeks kuantitasthe output quantity index is used for the production unit, at time the observation time t and t + 1, for teknologi the reference technology in the period k, k = t and t + 1, where:

$$MO_k\,(y_t, y_{t+1}, x_k) = \frac{E_k^O\,(y_{t+1}, x_k)}{E_k^O\,(y_t, x_k)}\,,\ k = t,\ t+1 \quad (3)$$

3. RESULTS AND DISCUSSION

3.1. UV-Vis Spectrophotometer of ZnO NPs

Data Envelopment Analysis (DEA) can provide an overview of the level of efficiency of the plantation sector on the island of Sumatra. If the efficiency value is close to 1 or 100% then the efficiency level is getting higher, and vice versa. The results of the level of plantation efficiency on the island of Sumatra are as follows:

Table 3. Plantation efficiency score in Sumatra Island based on CRS.

Province	2018	2019	2020	2021	2022	Mean	Rank
Aceh	1.000	1.000	1.000	1.000	1.000	1.000	1
North Sumatra	1.000	1.000	1.000	1.000	1.000	1.000	1
West Sumatra	1.000	1.000	1.000	0.957	1.000	0.991	9
Riau	1.000	1.000	1.000	1.000	1.000	1.000	1
Riau Island	1.000	1.000	1.000	1.000	1.000	1.000	1
Jambi	1.000	1.000	1.000	1.000	1.000	1.000	1
South Sumatra	1.000	1.000	1.000	1.000	1.000	1.000	1
Island Bangka Belitung	1.000	0.922	1.000	0.954	1.000	0.975	10
Bengkulu	1,000	1,000	1,000	1,000	1,000	1,000	1
Lampung	1,000	1,000	1,000	1,000	1.000	1.000	1
Mean	1.000	0.992	1.000	0.991	1.000	0.997	

Source: processed DEA Data, 2024.

Based on the results of DEA analysis on CRS, it is known that the overall average level of plantation efficiency in the province on the island of Sumatra is 0.997. If analyzed in each province, there are only two provinces that do not reach the maximum efficiency level or the two lowest, namely West Sumatra province and Bangka Belitung Islands province with efficiency values of 0.991 and 0.975, respectively. There are 8 provinces that achieve maximum efficiency levels, namely Aceh, North Sumatra, Riau, Riau Islands, Jambi, South Sumatra, Bengkulu and Lampung. Further analysis can be seen from the efficiency score based on VRS assumptions, as follows:

Table 4. Plantation efficiency score in Sumatra Island based on VRS.

Province	2018	2019	2020	2021	2022	Mean	Rank
Aceh	1.000	1.000	1.000	1.000	1.000	1.000	1
Sumatera Utara	1.000	1.000	1.000	1.000	1.000	1.000	1
Sumatera Barat	1.000	1.000	1.000	0.963	1.000	0.993	10
Riau	1.000	1.000	1.000	1.000	1.000	1.000	1
Kepulauan Riau	1.000	1.000	1.000	1.000	1.000	1.000	1
Jambi	1.000	1.000	1.000	1.000	1.000	1.000	1
Sumatera Selatan	1.000	1.000	1.000	1.000	1.000	1.000	1
Kepulauan Bangka Belitung	1.000	1.000	1.000	1.000	1.000	1.000	1
Bengkulu	1.000	1.000	1.000	1.000	1.000	1.000	1
Lampung	1.000	1.000	1.000	1.000	1.000	1.000	1
Mean	1.000	1.000	1.000	0.996	1.000	0.999	

Source: processed DEA Data, 2024.

Based on the table above, it can be concluded that the overall average level of plantation efficiency on the island of Sumatra on the VRS is higher than the efficiency score on the CRS, where the average overall efficiency on the VRS reached a value of 0.999. Analysis on each province, found that there are nine provinces that have reached a maximum efficiency level of 1,000, namely Aceh, North Sumatra, Riau, Riau Islands, Jambi, Bangka Belitung Islands, South Sumatra, Bengkulu and Lampung. While the lowest position there is only one province that does not reach the maximum efficiency level is West Sumatra province with a value of 0.993.

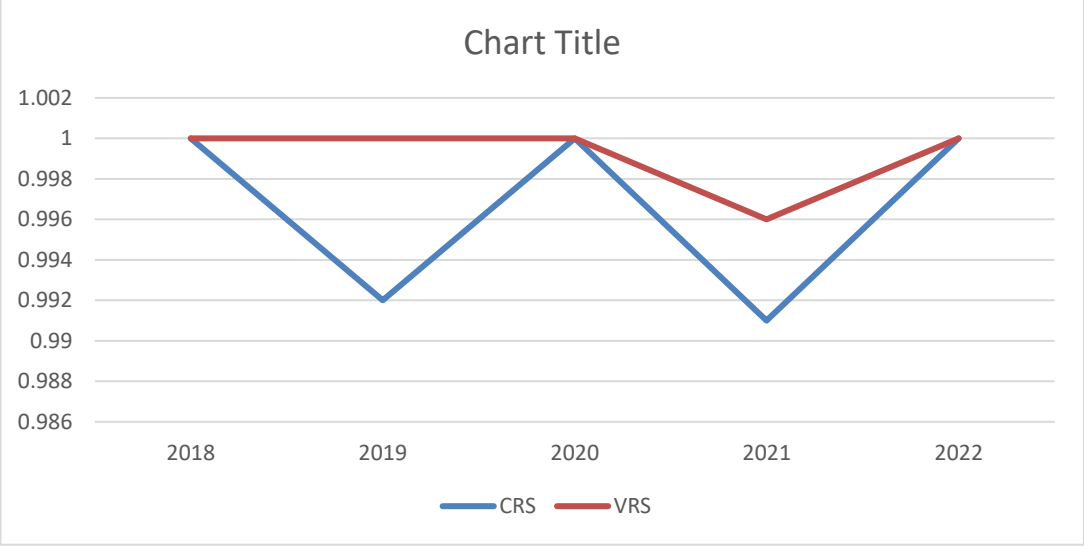

Figure 2. Trends in Plantation Sector Efficiency on the island of Sumatra.

Based on Figure 2, it can be concluded that the trend of plantation efficiency on the island of Sumatra fluctuates from year to year, precisely from 2018-2022. In particular, the CRS efficiency level in 2019 decreased to (0.992), which initially in 2018 experienced a maximum efficiency level, then in 2021 both CRS and VRS experienced a significant decrease of (0.991) and (0.996), respectively. The decline in the efficiency level of the plantation sector starting from 2021 is related to the occurrence of the global phenomenon of Covid-19 which is starting to spread throughout the world.

Table 5. Average Score of Malmquist Index of Sumatra Plantation

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
2018-2019	0.990	0.812	1.000	0.991	0.815
2019-2020	1.010	0.883	1.000	1.009	0.880
2020-2021	1.001	1.039	1.000	1.001	1.039
2021-2022	0.881	1.078	1.000	0.884	1.087
Mean	1.000	0.953	1.000	1.000	0.955

Source: Processed MPI Data, 2024.

From the table above, it can be seen that the average level of plantation productivity in Sumatra has decreased. This can be seen from the tfpch column with a value of (0.955). The decrease in Plantation productivity in Sumatra was mainly influenced by the decrease in technological changes in TECHCH (0.953), while the change in efficiency was constant (1,000). Plantation productivity levels in Sumatra increased from year to year, where in the period 2018-2019 productivity levels showed an increase. Then, in the period 2020-2021, productivity levels showed a significant increase. In the next period, there began to be an improvement in the level of plantation productivity in Sumatra, where productivity levels continued to increase until the 2022 period.

The study found that the plantation sector on Sumatra island showed a very high level of technical efficiency during the period 2018-2022. Based on the data Envelopment Analysis (DEA) approach, eight out of ten provinces including Aceh, North Sumatra, Riau, and Jambi have achieved a maximum efficiency score of 1,000. This indicates that inputs such as capital, land, labor, and fertilizer have been optimally utilized in producing the output of plantation commodities such as oil palm, rubber, and coffee. However, two provinces, namely West Sumatra and Bangka Belitung Islands, still showed efficiency values below the maximum, indicating the need to improve input management in the region. These results are supported by Homayoni (2022) this index provides a more stable and accurate measurement of productivity from year to year, although technological change remains a crucial factor and long-term productivity trends should be carefully evaluated. Next by Abdul et al (2022) that the average technical efficiency value of oil palm plantations in Indonesia, especially in West Sumatra, is 58.32%, which shows that there is still room for improvement in terms of efficiency.

On the other hand, this study shows that the level of productivity of the plantation sector in Sumatra is not in line with the level of efficiency. Through the Malmquist Productivity Index (MPI) approach, it is known that total productivity (TFPCH) has decreased on average (value 0.955), which is mainly caused by weak innovation and technological change (TECHCH = 0.953). This means that while resources are managed efficiently, limitations in the utilization of modern technology hinder the increase in output. In some years such as 2020-2021, productivity increases were seen, but the long-term trend still shows a slowdown that requires special attention. These results are supported by Atici et al (2018), showing that the decline in productivity is more due to the stagnation of technological change, while technical efficiency in some countries is relatively high. Because technological stagnation is the main cause of productivity decline, not technical inefficiency. Almost the same thing was also revealed by Shojaie (2024) that the early stages of input management and the limitations of technological innovation are the main causes of low productivity, although the efficiency at each stage is different. It needs innovation in the early and downstream stages to improve the performance of the production system.

The study also found that the impact of the Covid-19 pandemic in 2021 has led to a significant reduction in efficiency in some provinces. Disruptions to the supply chain, input distribution, and workforce affect efficiency scores that were previously consistently high. This demonstrates the vulnerability of the plantation sector to external shocks and reinforces the urgency to build a more resilient agricultural system through digitalization and logistical resilience. In terms of productivity, only provinces such as Bengkulu and Jambi showed a positive trend, which can be attributed to the adoption of technology and more intensive mentoring programs.

The novelty of this study lies in the use of a combination of DEA and MPI methods simultaneously to assess efficiency and

productivity at the provincial level on the island of Sumatra with a coverage of five years. Not only that, this study also expands the scope of input-output variables used, including additional variables of tea and tobacco production, and emphasizes the analysis of potential improvements in commodities that contribute to inefficiency such as coffee and palm oil. This is a plus compared to previous studies that only rely on technical efficiency approaches without reviewing aspects of productivity and technological innovation as a whole.

Thus, the findings and novelty of this study make an important contribution in the formulation of more adaptive and data-based plantation development policies. Strategic recommendations from the results of this study include the need for increased adoption of technology, partnership reform and legal certainty, as well as a focus on strengthening the main commodities that have not been optimal. This research not only contributes to the academic realm, but is also of practical relevance to plantation sector stakeholders and local governments in promoting sustainable natural resource-based economic growth on the island of Sumatra and Indonesia in general.

4. CONCLUSION AND RECOMMENDATIONS

This study aims to analyze the level of efficiency and productivity of the plantation sector on the island of Sumatra during the period 2018-2022 using data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI) approaches. The findings of this study indicate that the level of efficiency of the plantation sector is generally high, but there are still fluctuations from year to year. Berdasarkan hasil analisis DEA dengan pendekatan Constant Return to Scale (CRS), rata-rata skor efisiensi sektor perkebunan di Pulau Sumatra mencapai 0,997, sedangkan dengan pendekatan Variable Return to Scale (VRS) skor rata-ratanya mencapai 0,999. Hal This reflects that most besar provinces have managed sumber resources secara relatively efficiently. Eight of the ten provinces, namely Aceh, North Sumatra, Riau, KepulauanRiau Islands, Jambi, South Sumatra, Bengkulu, and Lampung, managed to achieve tingkat efisiensi maximum efficiency levels (score 1,000). Namun However, the provinces of West Sumatra and KepulauanBangka Belitung showed skor efficiency scores below the maximum, which indicates masih that there is still room for improvement in pengelolaan resource management dayain the regiontersebut.

Tren efficiency The annual efficiency trend shows that there penurunan efisiensi was a significant decrease in efficiency in tahun2021, whichkemungkinan is most likely due to the impact pandemiof the Covid-19 pandemic on rantai the supply chain,tenaga workforce, and distribution of production inputs. This decrease ini occurred both on the assumption of CRS (score 0.991) and VRS (score 0.996), which indicates the vulnerability sektor of the plantation sector terhadap gangguan eksternal to large-scale external disturbances besar. In terms of productivity, the results of MPI analysis show that on average, the plantation sector on the island of Sumatra has decreased productivity. The average Total Factor Productivity Change (TFPCH) score was recorded at 0.955, which indicates that produktivitas overall productivity decreased during periode the observation period. The decline was mainly due to a slowdown in perubahan technological change (TECHCH = 0.953), while efisiensi technical efficiency was relatively constant (EFFCH = 1.000). This shows that although the allocationanduse of inputs dilakukan is done efficiently, the lack kemajuan of technological progress has become hambatan a major obstacle in increasing the productivity sektor of the plantation sector.

Furthermore, only two provinces, namely Bengkulu and Jambi, showed an increase in productivity during the study period. This increase is driven by technological advances in the practice of cultivation and processing of plantation products. This condition reinforces the argument that the adoption of modern technology is very influential on the productivity of the agricultural and plantation sectors. An analysis of potential improvements also revealed that output from coffee and palm oil production were the two main factors contributing to inefficiencies. This indicates the need for more focused interventions on strengthening these key commodities, both through increased productivity and diversification of processed products.

Overall, the results of this study give an idea that although technical efficiency in the plantation sector of Sumatra island is relatively high, productivity is still a major challenge that needs to be overcome. Low innovation and technological mastery are obstacles that need to be addressed through adaptive policies, technology investment, and Human Resource Capacity Building. This study also emphasizes the importance of evaluating plantation development policies that have tended to be less than optimal in encouraging innovation and sustainability of the plantation sector at the regional level.

Based on the results of the study, there are five main policy recommendations that need to be considered to improve the efficiency and productivity of the plantation sector on the island of Sumatra. First, the adoption of technology must be strengthened through incentives for the use of modern agricultural tools and machinery and the utilization of digital innovations in the production process. Second, human resource capacity building is very important, especially through vocational education, technical training, and strengthening local-based counseling so that efficiency can be evenly distributed throughout the province. Third, the evaluation and reform of plantation policies is needed, especially related to farmer-company partnerships and legal certainty of land in order to attract investment and increase productivity. Fourth, strengthening supply chain and market access is an important strategy to reduce logistics costs and improve the competitiveness of plantation commodities in domestic and international markets. Fifth, it is necessary to focus improvements on key inefficient commodities, such as coffee and palm oil, through plant rejuvenation programs and technical coaching. The implementation of an integrative and data-driven policy will be the key to a more efficient, productive and sustainable transformation of the plantation sector.

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REFERENCES

Abdul, I., Sari, W. D., Haryanto, T., & Win, T. (2022). Analysis of factors affecting technical inefficiency on Indonesian palm oil plantations. *Scientific Reports, 12*(1). https://doi.org/10.1038/s41598-022-XXXXX

Alvianto, R., Setiawan, B. M., & Sumarjono, D. (2018). Analysis of production efficiency of tobacco farming in Sumberejo Village, Mranggen District, Demak Regency. *Agrisocionomics: Jurnal Sosial Ekonomi Pertanian, 1*(2).

Amalia, P., Suprayogi, Y., Azis, Y., et al. (2021). Analysis of the economic and social impact of infrastructure development in Indonesia. *Journal of Infrastructure Policy and Management, 4*(1), 1–11.

Asaad, M., Sitepu, R. K. K., & Martial, T. (2022). Production efficiency analysis of oil palm plantations: Stochastic frontier approach. *International Journal of Research and Review, 9*(12).

Atici, K. B., Ulucan, A., & Pay, I. U. (2018). The measurement of agricultural productivity change in OECD countries with fuzzy data. *RAIRO – Operations Research, 52*(3), 1003–1017. https://doi.org/10.1051/ro/2018018

Direktorat Jenderal Perkebunan. (2019). *62nd Plantation Day in 2019: Smallholders estate corporation for the welfare of planters*. https://ditjenbun.pertanian.go.id/2019/

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A, 120*(3), 253–290. https://doi.org/10.2307/2343100

Herdiansyah, H., Negoro, H. A., Rusdayanti, N., & Shara, S. (2020). Palm oil plantation and cultivation: Prosperity and productivity of smallholders. *Open Agriculture, 5*(1), 617–630. https://doi.org/10.1515/opag-2020-0069

Homayoni, A., Fallahnejad, R., & Lotfi, F. H. (2022). Cross Malmquist productivity index in data envelopment analysis. *4OR, 20*, 567–602. https://doi.org/10.1007/s10288-021-00478-2

Irawati, A., Sari, D. W., Haryanto, T., & Win, T. (2022). Analysis of factors affecting technical inefficiency of oil palm plantations in Indonesia. *UNAIR News*. https://unair.ac.id/analisis-faktor-faktor-yang-mempengaruhi-inefisiensi-teknis-perkebunan-kelapa-sawit-di-indonesia/

Maisarah, S., & Juliana, P. (2022). Palm oil production efficiency in Aceh Province. *Accounting and Development, 8*(2).

Matualage, A., Hariadi, S. S., & Wiryono, P. (2019). Palm oil plantation management in the pattern of PTPN II Prafi plasma core partnership with Arfak farmers in Manokwari, West Papua. *JSEP (Journal of Social and Agricultural Economics), 12*(1).

Milloy, J., Benea, C. B., Askins, K., Lin, W., Wilson, A., & Mitra, R., et al. (2022). Nationalism, geopolitics, and naval expansionism: From the nineteenth century to the rise of China. *Geopolitics, 23*(1).

Nainggolan, S., Wahyuni, I., & Ulma, R. O. (2019). Assessment of technical, allocative, and economic efficiency of rice farming to increase rice productivity. *Journal of Agribusiness and Local Wisdom (JALOW), 1*(1), 18–29.

Rita Hanafie. (2010). *Introduction to agricultural economics*. Alfabeta.

Sani, L., Khatiwada, D., Harahap, F., & Silveira, S. (2021). Decarbonization pathways for the power sector in Sumatra, Indonesia. *Renewable and Sustainable Energy Reviews, 150*, 111461. https://doi.org/10.1016/j.rser.2021.111461

Shirouyehzad, H., Hosseinzadeh Lotfi, F., Aryanezhad, M. B., & Dabestani, R. (2012). A data envelopment analysis approach for measuring employee efficiency: A case study. *South African Journal of Industrial Engineering, 23*(1).

Shojaie, S. E., Sadjadi, S. J., & Tavakkoli-Moghaddam, R. (2024). Malmquist productivity index for two-stage network systems under data uncertainty: A real-world case study. *PLOS ONE, 19*(7), e0307277. https://doi.org/10.1371/journal.pone.0307277

Sugiyono. (2014). *Quantitative, qualitative, and R&D research methods*. Alfabeta.

Sugiyono. (2021). *Statistics for research* (31st ed.). Alfabeta.

Uula, M. M. (2023). Analisis efisiensi dan produktivitas sektor perkebunan di Sumatra: Data envelopment analysis (DEA) dan Malmquist productivity index (MPI). *Conference in Sumatranomics (4th)*.

Wang, C. N., Lin, H. S., Hsu, H. P., Le, V. T., & Lin, T. F. (2016). Applying data envelopment analysis and grey model for productivity evaluation of the Vietnamese agroforestry industry. *Sustainability, 8*(11), 1139. https://doi.org/10.3390/su8111139

Ye, S., Qi, X., & Xu, Y. (2020). Analyzing the relative efficiency of China's Yangtze River port system. *Maritime Economics & Logistics, 22*(4), 602–621. https://doi.org/10.1057/s41278-020-00145-6

Zen, F., & Budiasih, B. (2019). Productivity and technical efficiency of coffee plantation businesses in South Sumatra and Lampung. *Journal of Indonesian Economic and Development Studies*.