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Strategic Optimization of Rubber Production at PT Perkebunan Nusantara IV, Region I, North Sumatra

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Abstrak

Optimalisasi produksi karet merupakan strategi penting untuk meningkatkan produktivitas dan efisiensi usaha perkebunan di tengah berbagai kendala teknis dan operasional. Strategi tersebut meliputi pemilihan klon unggul, penerapan teknik budidaya yang tepat, pemupukan berimbang, pengendalian organisme pengganggu tanaman, serta pengelolaan penyadapan dan pemeliharaan secara berkelanjutan. Namun demikian, produktivitas tanaman karet di PT Perkebunan Nusantara IV Wilayah I Sumatera Utara selama periode 2021–2024 menunjukkan tren penurunan, dari 1,09 ton karet kering per hektare pada tahun 2021 menjadi 0,98 ton karet kering per hektare pada tahun 2024. Kondisi ini mengindikasikan perlunya evaluasi terhadap strategi optimalisasi produksi yang telah diterapkan. Penelitian ini bertujuan untuk mengidentifikasi permasalahan utama dalam optimalisasi produksi karet dan merumuskan strategi yang efektif, khususnya terkait penggalian produksi pada areal rencana pabrik konversi, optimalisasi penggunaan stimulansia, penyesuaian frekuensi penyadapan pada periode gugur daun, serta pengendalian penyakit Pestalotiopsis. Metode penelitian menggunakan Quantitative Strategic Planning Matrix (QSPM) dengan pendekatan analisis SWOT melalui penyusunan matriks IFE, EFE, CPM, dan QSPM. Hasil penelitian menunjukkan bahwa strategi optimalisasi produksi karet yang efektif berfokus pada peningkatan produktivitas melalui penguatan kapasitas sumber daya manusia dan transformasi modal tenaga kerja secara lebih efisien.

Kata Kunci: Optimalisasi produksi; tanaman karet; QSPM; SWOT; produktivitas

Abstract

Rubber production optimization is a crucial strategy to enhance productivity and operational efficiency in plantation enterprises amid various technical and operational constraints. This strategy includes the selection of superior clones, the application of appropriate cultivation techniques, balanced fertilization, pest and disease management, as well as sustainable tapping and maintenance practices. Nevertheless, rubber productivity at PT Perkebunan Nusantara IV Region I, North Sumatra, exhibited a declining trend during the 2021–2024 period, decreasing from 1.09 tons of dry rubber per hectare in 2021 to 0.98 tons per hectare in 2024. This condition indicates the need for a comprehensive evaluation of the production optimization strategies that have been implemented. This study aims to identify the key constraints in rubber production optimization and to formulate effective strategies, particularly with regard to production enhancement in planned conversion factory areas, optimization of stimulant application, adjustment of tapping frequency during leaf-fall periods, and control of Pestalotiopsis disease. The research method employs the Quantitative Strategic Planning Matrix (QSPM) using a SWOT analysis approach through the development of IFE, EFE, CPM, and QSPM matrices. The results indicate that effective rubber production optimization strategies focus on improving productivity through strengthening human resource capacity and enhancing labor capital transformation in a more efficient manner..

Keywords: Production optimization; Rubber; QSPM; SWOT; productivity

1. Introduction

Rubber (Hevea brasiliensis) is one of Indonesia’s strategic plantation commodities, contributing significantly to rural economic development and serving as a primary raw material for downstream industries such as automotive, manufacturing, and healthcare. Despite its importance, rubber plantation productivity in several producing regions has shown a persistent decline in recent years. In North Sumatra, particularly in Region I, this declining trend reflects a combination of technical, managerial, and biophysical constraints that threaten the sustainability and competitiveness of rubber plantations. Previous international studies have shown that declining rubber productivity is closely associated with suboptimal tapping systems, inefficient stimulant application, latex

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losses due to incomplete collection, and the increasing incidence of leaf fall diseases caused by Pestalotiopsis species (Jacob et al., 2020; Priyadarshan, 2017). These constraints not only reduce latex yield but also induce physiological stress in rubber trees, thereby negatively affecting long-term productivity and plantation health. Consequently, improving rubber production performance requires a comprehensive evaluation of existing management practices and the formulation of integrated optimization strategies.

Effective rubber production optimization depends on institutional collaboration among plantation managers, technical personnel, and field workers to ensure coordinated planning and consistent implementation at the operational level. Collaborative management systems have been shown to enhance decision-making quality, improve labor efficiency, and support sustainable productivity outcomes in plantation-based industries (Basiron & Weng, 2020; Viswanathan et al., 2018). Within this framework, key optimization measures include improving the efficiency of stimulant application, adjusting tapping frequency based on leaf phenology, strengthening disease management strategies, and optimizing production areas in alignment with long-term plantation development plans. Stimulant management plays a crucial role in enhancing latex flow when applied at appropriate physiological stages, particularly during the latent leaf phase. Studies have demonstrated that optimized ethylene-based stimulant application can significantly increase yield while reducing tapping intensity and minimizing bark dryness (Jacob et al., 2020; Rodrigo et al., 2019). Similarly, scientifically informed adjustments to tapping frequency during leaf fall periods are essential to reduce tree stress while maintaining yield stability (Senevirathna & Nugawela, 2021). Moreover, the increasing prevalence of Pestalotiopsis leaf fall disease has highlighted the importance of integrated disease management approaches that combine chemical, biological, and cultural control measures to preserve canopy function and photosynthetic capacity (FAO, 2023; Jayasinghe et al., 2021).

In addition to technical constraints, managerial challenges such as uneven labor distribution, limited availability of skilled tappers, aging plantation structures, and inefficiencies in latex collection continue to hinder productivity improvement. These challenges are further intensified by plantation conversion and replanting programs, which require careful coordination to ensure productivity in existing stands while adopting best management practices in newly developed areas (Priyadarshan, 2017; Rodrigo et al., 2019). Therefore, rubber production optimization should not be viewed merely as a technical intervention but as an integrated strategic process involving institutional coordination, resource allocation, and continuous performance evaluation. This study aims to analyze rubber production optimization strategies at PT Perkebunan Nusantara IV Region I, North Sumatra, by identifying key internal and external factors affecting productivity and formulating effective strategic priorities to support sustainable rubber production.

2. Literature Review

A literature review provides a systematic synthesis of existing theories and empirical findings to identify patterns, advances, and unresolved research gaps within a particular field of study. In rubber (Hevea brasiliensis) production systems, optimization strategies have been widely discussed as a key mechanism for sustaining productivity amid increasing biotic stress, labor constraints, and operational inefficiencies. Prior studies emphasize that production optimization should integrate technical interventions—such as stimulant management, tapping system adjustment, and disease control—with managerial and institutional coordination to ensure long-term sustainability (Priyadarshan, 2017; Rodrigo et al., 2019). From a strategic management perspective, optimization is rooted in the concept of strategy as a set of deliberate choices that align organizational resources with environmental challenges to achieve long-term objectives. Strategy formulation involves evaluating comparative advantages, resource allocation efficiency, and sustainability orientation within dynamic production systems (Mashuri & Nurjannah, 2020). In the context of rubber plantations, effective strategies must reconcile biological crop characteristics with labor availability, cost efficiency, and market uncertainty, thereby linking agronomic performance to corporate planning frameworks such as the Rencana Kerja dan Anggaran Perusahaan (RKAP).

Biologically, rubber productivity is strongly influenced by genetic variability among clones, which exhibit distinct yield potentials, physiological responses to stimulation, and resistance to pests and diseases. International studies have demonstrated that clone-specific management—including tailored stimulant application and tapping frequency—is essential to achieve optimal latex yield without inducing physiological stress (Jacob et al., 2020; Flórez-Velasco, 2024). The inappropriate use of stimulants, particularly ethylene-based compounds, has been shown to accelerate latex flow in the short term but may compromise bark health and long-term productivity if applied without regard to phenological stages and clone characteristics (Rodrigo et al., 2019; Rahman et al., 2022). Tapping management represents another critical determinant of rubber productivity. Adjustments in tapping frequency during leaf fall periods have been widely recommended to reduce tree stress and support post-defoliation recovery (Senevirathna & Nugawela, 2021). Empirical evidence suggests that reducing tapping intensity during defoliation, followed by gradual normalization, contributes to yield stability and labor efficiency. However, the effectiveness of such adjustments depends on skilled labor availability and structured tapping workforce systems, which remain a persistent challenge in large-scale plantations.

Disease pressure, particularly leaf fall disease caused by Pestalotiopsis species, has emerged as a major constraint to rubber productivity in recent years. Studies across Asia and Africa report that severe defoliation reduces photosynthetic capacity and significantly suppresses latex output (Jayasinghe et al., 2021; Damiri, 2022). Integrated disease management approaches combining fungicide rotation, biological agents such as Trichoderma spp., and canopy management have been shown to effectively suppress disease incidence while supporting ecological sustainability (FAO, 2023; ResearchGate studies, 2022–2024). These findings highlight the importance of embedding disease control within broader production optimization strategies rather than treating it as a standalone intervention. Beyond technical dimensions, rubber cultivation plays a crucial socio-economic role, particularly in rural areas where plantation activities constitute a primary source of household income. Inefficient management practices, labor shortages, and delayed tapping schedules directly affect productivity and farmer welfare (Elinur et al., 2019). Recent empirical studies indicate that coordinated management systems—integrating stimulant regulation, labor restructuring, and field-level monitoring—can significantly improve latex yield and operational efficiency (Nugrahani et al., 2022; Nur Halimah et al., 2024).

Despite extensive research, several gaps remain evident in the existing literature. First, limited attention has been given to the strategic integration of tapping labor restructuring, particularly the transition from self-tapping systems to tapping power (TP) models under conditions of labor scarcity. Second, stimulant application practices remain inconsistent, reflecting the absence of standardized, clone-specific guidelines adaptable to local environmental conditions. Third, production optimization in conversion planting areas—covering more than 4,000 hectares planned for 2025—has not been sufficiently examined from a strategic and institutional perspective. Finally, although Pestalotiopsis outbreaks are widely documented, empirical studies rarely integrate disease dynamics with labor management and production planning within a unified strategic framework. Therefore, existing literature underscores the need for an integrated rubber production optimization model that simultaneously addresses biological, managerial, and institutional dimensions. This study contributes to the literature by formulating strategic priorities for rubber production optimization using a structured decision-making approach, with particular emphasis on stimulant management, tapping frequency adjustment, labor system restructuring, and disease control to support productivity targets and sustainability objectives in 2025 and beyond.

3. Research Method

This This study employs a quantitative research design to systematically examine the strategies, operational procedures, and key determining factors influencing both the effectiveness and constraints of rubber production optimization. The primary objective is to identify strategic approaches capable of enhancing production volume and productivity, particularly in adolescent and mature rubber stands, which constitute the most productive age categories within plantation operations. A quantitative approach is adopted to enable the measurement and analysis of relationships among managerial strategies, stimulant application practices, tapping management, and disease control mechanisms. This approach provides an evidence-based framework for evaluating which combinations of interventions generate the highest productivity outcomes under varying plantation conditions. To support strategic decision-making, this study applies the Quantitative Strategic Planning Matrix (QSPM) as the main analytical tool. QSPM facilitates the systematic assessment, prioritization, and formulation of optimal strategies by quantifying both internal and external strategic factors and determining their relative importance in achieving sustainable productivity improvements.

The QSPM framework allows for a structured comparison of alternative strategic options, assisting management in identifying policies, operational procedures, and field-level interventions that most significantly contribute to achieving production targets. By integrating quantitative assessment with managerial judgment, this study provides a comprehensive understanding of how PT Perkebunan Nusantara IV (PTPN IV) Regional I North Sumatra formulates, implements, and refines rubber production optimization strategies within real plantation contexts. Primary data were collected directly from the field through systematic observations and in-depth interviews with key stakeholders involved in the planning and execution of rubber production optimization initiatives. Respondents included Plantation General Managers, Plantation Managers, Inspectors, technical plantation staff, and rubber tapping workers, each offering distinct perspectives on operational efficiency and strategic implementation. The interviews focused on identifying current production constraints, the effectiveness of stimulant application, tapping labor management, and ongoing control measures for Pestalotiopsis leaf fall disease, which has been a major contributor to productivity decline in several plantation blocks.

Field observations were conducted to complement the interview data, enabling direct documentation of production activities, stimulation procedures, latex collection efficiency, and the physiological condition of adolescent and mature rubber stands. The combination of interviews and observations enhances data validity through methodological triangulation, ensuring that the findings accurately reflect actual plantation conditions. Secondary data were obtained from internal company documents and official plantation records, including annual reports, production performance data, stimulant usage records, Pestalotiopsis disease control reports, and crop field documentation detailing production and productivity trends. Relevant corporate policy documents were also reviewed to examine management directives related to production targets, optimization strategies, and sustainability frameworks.

These secondary data sources provide a longitudinal perspective on operational performance and support the quantitative analysis of strategic effectiveness. The integration of primary and secondary data enables a comprehensive evaluation of how internal management systems, production techniques, and disease control practices interact to influence the success of rubber production optimization strategies across the operational area of PTPN IV in North Sumatra.

4. Results and Discussion

The The analysis of limitations in rubber production optimization strategies focuses on identifying and evaluating the gap between existing operational conditions and the desired state of productivity and sustainability. This analytical approach aims to define the boundaries of operational effectiveness by examining how current agronomic practices, technical capacities, and management systems either support or constrain the achievement of long-term production objectives. Through this framework, the study identifies critical limiting factors that contribute to suboptimal production performance, thereby enabling the formulation of targeted strategies to mitigate constraints and enhance overall plantation efficiency. The identification of production limitations is conducted through a systematic comparison between the “as-is” condition and the “to-be” or ideal condition. Key operational dimensions assessed include labor capacity and distribution, tapping frequency, stimulant application practices, and disease management effectiveness. This comparison not only reveals internal inefficiencies within the production system but also highlights external pressures, such as environmental variability, resource constraints, and institutional alignment, which collectively influence rubber productivity outcomes.

Efforts to improve rubber productivity must therefore begin with a diagnostic evaluation of field-level constraints, plant physiological potential, and the adequacy of critical resources—particularly the availability and skill level of tapping labor. The sufficiency and competence of tapping personnel, commonly referred to as tapping power (TP), represent a decisive factor in achieving optimal latex extraction rates, especially in adolescent and mature rubber stands where tapping consistency directly affects yield. In plantation blocks where tapping labor is limited or unevenly allocated, productivity tends to decline even when other agronomic inputs are properly managed. Furthermore, the success of production optimization initiatives must align with the company’s broader corporate and strategic framework, particularly the long-term plantation development plans established by PalmCo Sub-holding. Sustainable rubber production is not solely determined by short-term yield improvements but also depends on integrated planning that balances current exploitation with regeneration cycles, replanting programs, and workforce sustainability. Consequently, production optimization policies must be harmonized with corporate objectives related to resource efficiency, land-use planning, and human resource management to ensure that productivity gains are both measurable and enduring. Ultimately, limitation analysis provides valuable insights into how resource constraints, managerial decisions, and operational practices interact to shape the effectiveness of rubber production strategies. By systematically mapping discrepancies between current and optimal conditions, plantation management can prioritize corrective actions, improve tapping and stimulation efficiency, and allocate labor resources more effectively, thereby ensuring that productivity improvements contribute meaningfully to the company’s long-term sustainability objectives.

Table 1. Internal Factor Analysis and Eksternal Factor Analysis (IE) PTPN IV Regional

Faktor Strategi	Bobot	Strategi 1 (AS)	Strategi 1 (TAS)	Strategi 2 (AS)	Strategi 2 (TAS)	Strategi 3 (AS)	Strategi 3 (TAS)
InternalFactor							
Strength (S)							
S1	0.12	4	0.48	4	0.48	3	0.36
S2	0.09	4	0.36	3	0.27	3	0.27
S3	0.07	4	0.28	2	0.14	2	0.14
S4	0.06	2	0.12	2	0.12	2	0.12
Jumlah S	**0.34**		**1.30**		**1.01**		**0.89**
Weakness (W)							
W1	0.07	2	0.14	3	0.21	2	0.14
W2	0.05	3	0.15	2	0.10	2	0.10
W3	0.04	3	0.12	2	0.08	2	0.08
W4	0.03	2	0.06	2	0.05	2	0.06
Jumlah W	**0.19**		**0.47**		**0.47**		**0.38**
EksternalFactor							
Opportunity (O)							
O1	0.11	4	0.44	3	0.33	2	0.22
O2	0.09	3	0.27	3	0.27	2	0.18
O3	0.07	3	0.21	3	0.21	2	0.14
O4	0.06	0	0.00	2	0.12	2	0.12
Jumlah O	**0.33**		**0.94**		**0.93**		**0.66**
Threat (T)							
T1	0.05	2	0.10	2	0.10	2	0.10
T2	0.05	2	0.10	2	0.10	2	0.10
T3	0.04	2	0.08	2	0.08	2	0.06
T4	0.02	0	0.00	2	0.07	2	0.03
Jumlah T	**0.16**		**0.40**		**0.35**		**0.29**
TOTAL	**1.02**		**3.11**		**2.76**		**2.28**

The results of the Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) analyses are presented in Table 1. The IFE–EFE framework is used to assess the relative strengths, weaknesses, opportunities, and threats influencing rubber production performance at PT Perkebunan Nusantara IV (PTPN IV), Regional I, North Sumatra. The internal factor assessment indicates a total strength score of 1.30 and a total weakness score of 0.47, reflecting that the company's internal capabilities outweigh its internal constraints. Meanwhile, the external factor assessment produces a total opportunity score of 0.94 and a total threat score of 0.40, suggesting that the external environment presents more favorable opportunities than risks. The company's position within the strategic space is determined using the difference between strengths and weaknesses for the internal dimension (X-axis: 1.30 − 0.47 = 0.83) and the difference between opportunities and threats for the external dimension (Y-axis: 0.94 − 0.40 = 0.54). These coordinates place PTPN IV Regional I within the Strength–Opportunity (SO) quadrant, indicating that the organization is in a favorable position to pursue aggressive growth and optimization strategies by leveraging internal strengths to capitalize on external opportunities.

Table 2 SWOT Quadrant results

In the Matching Stage of strategic formulation, the Internal–External (IE) Matrix is employed as a key analytical instrument to align internal capabilities with external environmental conditions. The IE Matrix supports management in determining whether the organization should pursue strategic expansion, maintain existing strategies, or improve efficiency in current operations. When used in conjunction with the SWOT Matrix, the IE Matrix facilitates the generation of alternative strategic options based on a comprehensive evaluation of internal and external factors.

- The integration of the IE and SWOT frameworks enables the formulation of four strategic categories:
- Strength–Opportunity (SO) strategies, which leverage internal advantages to exploit external opportunities;
- Weakness–Opportunity (WO) strategies, which address internal limitations by utilizing external opportunities;
- Strength–Threat (ST) strategies, which use internal strengths to mitigate external risks; and
- Weakness–Threat (WT) strategies, which aim to minimize vulnerabilities and avoid external threats.

Based on the company's strategic position within the SO quadrant, the analysis prioritizes strategies that emphasize operational strengthening, production excavation, and labor optimization to maximize productivity gains.

Table 3 Ranking of Strategy after QSPM

Ranking	Strategy	Competitive	Operational Effective	Sustainable	Score Total
1	The arrangement of own power as much as 322 HK which was replaced with deres TP power.	7.90	8.50	8.30	**8.23**
2	Maximize production excavation in the area deres TP.	8.30	8.20	8.00	**8.17**
3	Optimizing production excavation on the 2025 kindergarten plan area of 4,091 Ha.	8.40	8.10	7.90	**8.13**
4	Changes in the frequency of tapping during leaf fall and control of *Pestalotiopsis*.	7.80	8.00	8.10	**7.97**
5	Optimization of stimulants by 30% when the condition of the leaves >60% latent.	7.70	8.00	8.10	**7.93**

The strategic alternatives generated through the Matching Stage are further evaluated using the Quantitative Strategic Planning Matrix (QSPM), as presented in Table 3. The QSPM analysis ranks strategies based on their Total Attractiveness Score (TAS), which reflects their relative feasibility, competitiveness, operational effectiveness, and sustainability. The results indicate that the reorganization of 322 internal labor units (HK) by substituting them with TP-based tapping personnel achieves the highest TAS value of 8.23, making it the top strategic priority. This finding underscores the critical importance of tapping labor restructuring in improving operational efficiency and enhancing latex extraction performance.Other high-ranking strategies include maximizing production excavation in TP-designated areas, optimizing production in the 2025 conversion plan area covering approximately 4,091 hectares, adjusting tapping frequency during leaf-fall periods coupled with Pestalotiopsis disease control, and optimizing stimulant application by 30% under leaf latent conditions exceeding 60%. Although these strategies exhibit slightly lower TAS values, they remain complementary and supportive of the primary labor restructuring initiative.

Overall, the QSPM results demonstrate that human resource optimization—particularly tapping labor restructuring—constitutes the most influential and feasible strategy for enhancing rubber production performance. When implemented alongside supportive agronomic and disease management measures, this strategy provides a robust pathway for achieving sustainable productivity targets at PTPN IV Regional I, North Sumatra.

5. Conclusion

This study concludes that the optimization of rubber production at PT Perkebunan Nusantara IV Regional I, North Sumatra, is primarily constrained by limitations in tapping labor availability, suboptimal stimulant application practices, insufficient production excavation in designated conversion-plant areas, inappropriate tapping frequency adjustments during the leaf-fall period, and inadequate control of Pestalotiopsis leaf fall disease. These factors collectively contribute to declining productivity and highlight the need for integrated operational and managerial interventions. The findings demonstrate that the implementation of a structured rubber production optimization strategy significantly enhances operational efficiency, improves rubber output quality, and supports more timely and evidence-based managerial decision-making. The application of the Quantitative Strategic Planning Matrix (QSPM) identifies labor restructuring—specifically the substitution of internal labor units with tapping power (TP) personnel—as the most effective strategic priority, as it minimizes operational inefficiencies and reduces potential productivity losses.

Furthermore, this study provides practical managerial implications for strengthening plantation operational management systems. The recommended strategies support sustainable production practices through improved workforce utilization, optimized tapping and stimulation management, and enhanced disease control. Collectively, these measures contribute to improving the long-term competitiveness, productivity stability, and sustainability of the rubber plantation sector.

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