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# Integrating Supply Chain Management into Food Estate Models for Enhanced Food Security

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**Abstract.** This study analyzes the integration of supply chain management (SCM) within a food estate model on lowland swamp agroecosystems to strengthen national food security. A descriptive–analytical survey was conducted for eight months involving 60 farmers from three farmer groups in Muara Belida, South Sumatra. Performance was assessed using the SCOR v13.0 framework, value-added analysis (Hayami method), KPI weighting (ANP), and performance measurement (OMAX with Traffic Light System). Results show an overall SCM performance index of 7.892 (yellow category), with "Deliver" (8.280), "Make" (8.258), and "Return" (8.025) performing relatively well, while "Plan" (7.520) and "Source" (7.758) remain moderate. Policy and managerial implications highlight the need for farmer training, adoption of climate-resilient crop varieties, demand forecasting systems, and formal contractual partnerships to stabilize supply and reduce transaction costs. Findings further reveal that SCM integration enhances value addition at the farmer level and mitigates systemic risks, thereby contributing to food security by reducing logistics costs and building supply chain resilience. This research provides empirical evidence that incorporating SCM into food estate development constitutes a critical strategy for sustainable agro-industrial cluster management in lowland swamps and for achieving national food security.

**Keywords**: food estate**;** food security**;** Key Performance Indicators (KPIs)**;** SCOR Framework; Supply Chain Management (SCM)

## INTRODUCTION

Food security has emerged as an urgent global issue in the context of rapid population growth, climate change, and increasingly volatile international food markets (Nchanji et al., 2021). Governments worldwide have responded by designing large-scale agricultural initiatives to secure food supply, stabilize prices, and promote sustainability. In Indonesia, the food estate program has been introduced as a flagship policy to strengthen national food resilience, including development in lowland swamp areas such as Muara Belida, South Sumatra. This location holds significant promise due to its vast underutilized land resources, but it also presents ecological fragility, seasonal flooding, and logistical difficulties that make agricultural management particularly complex (Setiawan & Hidayat, 2024).

A human community's ability to obtain sufficient food has historically been a decisive factor in its survival (Basundoro & Sulaeman, 2022). Without adequate food security, food instability and varied low nutritional intakes will cause widespread hunger in a society. The administration is concerned about this situation and wants to promote and build a solid movement for food security (Divya, 2014; Qori et al., 2025). Additionally, based on an earlier study by the research team, it is crucial to make sure that food security is prepared on all fronts, from upstream producers to downstream consumers of agricultural commodities (Agustina et al., 2019).

The impact of the political economy's dynamics surrounding the food crisis, which is still changing food sector policy, cannot be divorced from Indonesia's long-standing participation in the global political economy (Lula & Efriza, 2020). One of the "objectives" for developing a food security strategy in the contemporary period of government is to build a sizable food barn,

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also known as a “food estate”. Since 2014, 190,000 hectares of land have been used for the development of the food estate initiative. spread in the provinces of Maluku, Papua, West Sumatra, South Sumatra, Central Kalimantan, and East Kalimantan.

The food estate program is an idea for securing our food supply that is based on farming, plantations, and fishing. Therefore, agricultural, plantation, and fishery goods, both vegetable and animal, are all developed as part of the food estate, with staple food being the most notable and significant existence (Salshabila et al., 2021). Self-reliance, sovereignty, and food security are some of the interrelated components of the food estate program that aims to provide food security (Alsafana et al., 2023). Food estate is a scheme for the expansion of large-scale food plant farming activities. The food estate area program seeks to increase domestically produced food's accessibility in a sustainable way.

This implies that the equilibrium of every element of the agricultural ecosystem involved in the growth of the food estate will be maintained. Therefore, regional development, sector and sub-sector integration, sustainable environmental management, and community economic empowerment are the strategies employed in the development of the food estate area (Rahmawasiah & I Nyoman, 2025; Tiara et al., 2025). Since the middle of 2018, Muara Belida District in Muara Enim Regency has served as the focal point of the food estate initiative in South Sumatra. This initiative, which aims to enhance national food reserves from upstream to downstream, will be handled in a contemporary manner and is still in place in the midst of the Covid-19 epidemic (Ahmad & Mohammad, 2021; Hotden et al., 2021). One of the most effective projects for securing future food security in South Sumatra specifically and Indonesia generally is the food estate program in the Muara Belida sub-district.

The *lebak*-swamp land, which spans 61.6 Km2 and is traversed by the Belida River, is the focal point of the Muara Belida District's food estate initiative, making it extremely strategically important. With the idea of combining food production into a sizable plot of land separated into many clusters, the Muara Belida food estate scheme was created. The term "cluster" refers to a geographical concentration of farmers, agribusinesses, supporting organizations, and related entrepreneurs who are involved in a single chain of production for an agricultural product, interact with one another, and create value networks by working together to overcome obstacles and seize opportunities. Three key factors, namely the investors, the government, and the community, need to be addressed in order to expedite the food estate initiative (Yunita et al., 2024). It can be argued that the support from the government side has largely been trouble-free throughout the two years that the food estate program has been operating in Muara Belida. However, the most essential reform must be made on the part of the community and investors.

Identified the community and investors as the two sides that contribute to modernisation without development. Due to the "best knowledge" of the government and public institutions. The goal of the food estate program should be to strengthen and promote local employees' capacity and abilities through education and community. Food estate programs in Muara Belida can aim to take all the commercial potential or added value that exists in the entire series of agricultural activities in this program and teach business values among farmers (Agustina et al., 2021).

The Muara Belida food estate initiative needs to address the issues of food distribution, lowering high logistical costs, and effective food stock management. Collaboration amongst the different parties involved in the food supply chain is necessary to strengthen the Muara Belida food estate program. Farmers from the Muara Belida tribe who are a part of the food estate program need to be connected to the business community. This collaboration focuses on the

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network of business organizations involved in supply chain management integration from upstream to downstream (Andhika et al., 2023).

Despite the program's strategic importance, much of the existing research on food estates in Indonesia has concentrated on technical cultivation, land conversion, and short-term productivity outcomes. These studies rarely address the broader organizational and systemic dimensions that determine long-term performance (Islah et al., 2021; Juhandi et al., 2023). In particular, the role of Supply Chain Management (SCM) remains underexplored, even though it represents a key lever for achieving efficiency, resilience, and sustainability in agricultural systems (Rohim & Setiawan, 2021). SCM goes beyond farm-level productivity by encompassing planning, sourcing, production, distribution, and returns, enabling integrated coordination from input suppliers to end consumers (Ahmed & Sundarakani, 2021).

The lack of empirical studies on SCM in swamp-based food estates, therefore, constitutes a critical research gap that this study seeks to address. International experiences reinforce the centrality of SCM in agricultural performance in Brazil, Vietnam, Thailand, China, and the Middle East. These cases suggest that food estate initiatives cannot succeed solely through agronomic innovation but require systemic supply chain coordination.

Within Indonesia, early assessments of food estate programs reveal mixed outcomes. While land allocation and planting targets have been achieved in some regions, long-term sustainability is often constrained by fragmented supply chains, limited farmer capacity, and weak linkages to markets (Arifin et al., 2022; Purwanto & Siregar, 2023). Research also indicates that SCM flexibility is positively associated with agricultural firm performance, especially in adapting to dynamic environments (Itang et al., 2022). These findings highlight the need to assess how SCM integration influences food estate performance in specific ecological and institutional contexts, such as the Muara Belida lowland swamp.

This study addresses the following research questions: 1) What is the current performance level of supply chain management in the Muara Belida food estate? 2) What are the barriers and drivers shaping SCM integration in this context? 3) How does SCM integration contribute to improving yields, reducing inefficiencies, and supporting sustainable food security at both local and national levels?

Building on these questions, the study hypothesizes that effective SCM integration across the SCOR dimensions will strengthen the overall performance of swamp-based food estates.

By situating SCM within the unique ecological challenges of lowland swamps, this research introduces a novel empirical perspective into Indonesia's agricultural policy discourse, particularly in Muara Belida, South Sumatra. The significance of this research operates at two levels. Locally, it aims to support farmers and farmer group associations (Gapoktan) in Muara Belida by identifying supply chain weaknesses and opportunities, thereby fostering more efficient, sustainable, and market-oriented production systems. Nationally, it contributes to evidence-based policymaking by demonstrating that food estate success requires more than production targets.

By positioning the Muara Belida case within a comparative global framework, drawing lessons from Brazil's logistics integration, Thailand's cooperative structures, Vietnam's digital traceability platforms, and China's resilience strategies, this study underscores SCM's role as a bridge between production and consumption. This bridging function is essential for ensuring supply continuity, maintaining product quality, and stabilizing food prices amid global uncertainty (Abdul-Rahman et al., 2023; Zhang et al., 2022). Ultimately, this research highlights how swamp-based food estates can evolve from production-centric

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projects into resilient agro-industrial systems, strengthening Indonesia's long-term food security while contributing to the broader academic literature on SCM and food systems sustainability.

## METHODS

Research Types. With a questionnaire serving as the primary data collecting tool, this study is a descriptive analytical survey that draws samples from a population (Nathan et al., 2025). This study adopted a descriptive–analytical survey design to investigate the integration of supply chain management (SCM) within the lebak-swamp land food estate model in Muara Belida District, Muara Enim Regency, South Sumatra. The methodological framework was structured around three critical SCM stages: (1) the Integrated Enterprise Stage, which emphasizes institutional arrangements and coordination among stakeholders; (2) the Supplier Network Stage, which examines supplier management and corporate partnerships between farmers and processing firms; and (3) the Distributed Network Stage, which focuses on cooperative-based distribution management to end consumers (Samah et al., 2025). This design provided an integrated approach for assessing both structural and performance dimensions of the food estate supply chain.

**Data Collection Procedures**. Primary data were obtained through a combination of structured questionnaires and semi-structured interviews administered to key supply chain actors. The first step in the snowball sampling technique for the sample at this point is to identify the three combined farmer groups in the Muara Belida District that each have 20 farmer members, or 60 sample farmers (32.14%), as the primary suppliers of the three combined groups. Respondents included farmer group leaders (Gabungan Kelompok Tani or Gapoktan), individual farmers, representatives of processing companies, and local government officials. The questionnaire consisted of closed-ended Likert-scale items (ranging from 1 = strongly disagree to 5 = strongly agree), which measured constructs such as supply chain integration, performance indicators, production costs, and distribution efficiency. Instrument development was guided by the Supply Chain Operations Reference (SCOR) model v13.0, an established framework for standardizing supply chain performance metrics across diverse industries (Markus et al., 2025).

To ensure content validity, the questionnaire was reviewed by three SCM academics and two industry practitioners. Following revisions, a pilot test was conducted with ten respondents to assess clarity and reliability. Cronbach's alpha coefficients for all constructs exceeded the threshold of 0.70, indicating satisfactory internal consistency. In addition, semi-structured interviews were employed to capture nuanced perspectives regarding institutional linkages, trust, and informal practices that might not be fully captured through quantitative measures. Secondary data were sourced from company reports, government agricultural statistics, and official documentation of the Muara Belida Food Estate program.

**Data Analysis Methods.** In accordance with the goals of this study, numerous stages of this research were undertaken. In order to achieve the first goal of this study, a supply chain performance measurement model based on the SCOR model version 13.0 was used to assess the effectiveness of supply chain management in the food estate model of the *lebak*-swamp land at the supplier network stage in Muara Belida (Ozden & Fusun, 2023).

**Sampling Strategy**. Given the relatively small and interconnected population of actors in the food estate supply chain, a snowball sampling technique was adopted. The process began with three combined farmer groups (approximately 20 members each) identified as primary suppliers. Initial respondents—primarily group leaders—were asked to nominate upstream and downstream stakeholders, thereby expanding the sample

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through existing trust-based relationships. This approach was deemed appropriate for populations that are undocumented or difficult to access through conventional probabilistic techniques (Xianwei et al., 2025).

The final sample comprised 60 farmers, representing 32.14% of the known farmer population, and an additional 15 stakeholders, including processing firms, distributors, and government officials. This ensured broad representation across the supply chain network and provided sufficient data variability for analysis.

**Bias Considerations and Mitigation.** Three potential biases were anticipated in the study design. First, selection bias was acknowledged due to the non-random nature of snowball sampling. Second, social desirability bias may have influenced respondents to overstate cooperative behavior or performance achievements. Third, recall bias was possible when respondents were asked to provide production and distribution data retrospectively. To mitigate these risks, multiple strategies were employed: triangulation of survey results with interview findings and secondary records; assurances of confidentiality and anonymity to minimize socially desirable responses; and the use of time-specific prompts during interviews to enhance recall accuracy.

**Data Analysis Procedures.** Data analysis was conducted in five stages, combining both quantitative and simulation-based techniques:

1. **Performance Measurement**: Supply chain performance was measured using the SCOR framework across its five process categories: Plan, Source, Make, Deliver, and Return. A total of 38 validated Key Performance Indicators (KPIs) were adopted, consistent with prior research (Diego et al., 2025).
2. **KPI Weighting**: The relative importance of each KPI was determined using the Analytic Network Process (ANP). Pairwise comparisons were conducted with Super Decisions software, ensuring that the consistency ratio (CR) did not exceed 0.1, as recommended by Saaty (1980).
3. **Performance Categorization**: KPI scores were normalized and subsequently categorized into green, yellow, and red performance zones using the Objective Matrix (OMAX) method integrated with a traffic-light system.
4. **Value-Added Analysis**: The Hayami method was applied to assess the added value generated by key products at the distributed network stage. Outputs were classified as low (<15%), moderate (15–40%), or high (>40%) based on standard thresholds (Hayami et al., 1987).
5. **Dynamic Simulation**: Powersim software was used to simulate potential improvement scenarios for underperforming KPIs, allowing the identification of leverage points for systemic enhancement of supply chain integration.

Additionally, descriptive statistics, reliability testing, and validity assessments were carried out using SPSS v26 and Microsoft Excel. This multi-method approach provided both diagnostic and predictive insights into supply chain performance.

**Instrument Validation.** The SCOR-based KPI set underwent a two-stage validation process. First, content validity was established through expert panel reviews involving academics and practitioners. Second, empirical validation was conducted via the pilot test, followed by reliability analysis. Cronbach’s alpha values exceeded 0.70 for all constructs, confirming internal consistency. Construct validity was further evaluated using Average Variance Extracted (AVE), with all values surpassing the minimum criterion of 0.50. For the ANP procedure, all pairwise comparisons were examined for logical consistency prior to finalizing the weight structure (Sayyed, 2025).

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**Limitations and Assumptions.** Several methodological limitations should be acknowledged. First, the use of non-random sampling restricts the generalizability of findings beyond the study population. Second, reliance on self-reported data may introduce inaccuracies, despite efforts to mitigate them. Third, while the SCOR framework provides a robust means of evaluating operational efficiency, it does not fully capture socio-cultural and behavioral dimensions of supply chain integration (Azam et al., 2025).

The study was conducted under several assumptions: respondents were assumed to provide honest and accurate responses; the SCOR model was assumed to be applicable within lebak-swamp agribusiness contexts; and the performance indicators were assumed to reflect actual operational performance rather than aspirational targets. These limitations and assumptions were carefully considered in the interpretation of results, ensuring that conclusions remained valid within the study's defined scope.

## RESULTS AND DISCUSSION

### Description Food Estate in Muara Belida District, South Sumatra

The Muara Belida District in Muara Enim Regency, South Sumatra, is characterized by fertile swamp-based wetlands, with 70% of its 61.6 km² area used for agriculture. This region has been prioritized for food estate development due to its strategic location along the Belida River, making it an important site for integrating upstream–downstream agricultural management. The COVID-19 pandemic further underscored the vulnerability of food systems and the need for resilient supply chain strategies (Najmah et al., 2022; Park, 2022)

The majority of the Muara Belida sub-district is made up of swampy wetland lands. It has a total area of 61.6 km2, of which 70% is agricultural land, with a population density of roughly 663 inhabitants per km2. The development of food estates takes place in a number of clustered regions that make up the overall area. The idea of cluster development in the food estate region is based on size, with each cluster covering a 10,000 ha area and comprising of numerous clusters that each cover between 2,000 and 5,000 ha. The central government, regional governments, BUMN, other ministries, and farmers will all be involved in the establishment and maintenance of this food estate. According to spatial data from the Ministry of PUPR, the majority of this food estate area is a part of the *lebak*-swamp rice fields, which are located on the banks of the Belida River.

In line with the research questions outlined in the Introduction—namely assessing the current performance level of supply chain management in the Muara Belida food estate, identifying barriers and drivers of integration, and evaluating its contribution to food security—this section presents the empirical findings.

### Measuring Supply Chain Integration Activities

This study systematically applied a multi-stage analytical framework to evaluate supply chain performance in the Muara Belida food estate. By incorporating farmer groups' or *Gapoktan* collaboration in the production of high-quality rice, the food estate program's supply chain management operations are carried out in the wetlands of Muara Belida, Muara Enim, South Sumatra, Indonesia. Through a cooperative system, combined farmer groups, such as Gapoktan, that grow rice engage with the rice agro-industry enterprise, Buyung Poetra Sembada Inc., in the provision of rice seeds, fertilizers, and agricultural infrastructure. To oversee *Gapoktan* in maintaining the quality of the rice that will be produced five times during the planting season, the rice agro-industry firm distributes rice seeds in accordance with their standards. In order to assess the viability of harvesting the rice seeds, this supervision entails inspection of the vegetative phase, inspection of the flowering phase, inspection

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of the ripening phase, inspection of the harvesting equipment, and inspection of the processing. The company in the rice agro-industry is now able to receive harvest dry grain as a consequence of their partnership with a number of farmer organizations as suppliers. This grain is used as the primary ingredient in the production of premium rice (Hugo et al., 2025).

**Overall Supply Chain Performance Index**. The findings of the investigation of the Muara Belida farmers group association's actions in the rice supply chain from five viewpoints. The integrated supply chain performance measurement between Buyung Poetra Sembada Inc. (BPS) and the Muara Belida Farmers Group Association (MBFGA) resulted in an overall Supply Chain Performance Index (SCPI) score of 7.892 on a 0–10 scale (equivalent to 78.92%), which falls within the yellow category according to the Traffic Light System. This indicates moderate performance, suggesting that while certain processes are operating efficiently, others require significant improvement to meet the expected benchmarks.

**Performance by SCOR Perspective**. When disaggregated by the SCOR model perspectives, the highest performance was observed in Deliver (8.280), followed by Make (8.258) and Return (8.025), all within the green category (>8.0). Conversely, Source (7.758) and Plan (7.520) fell within the yellow category, indicating that procurement and planning activities are underperforming relative to agreed targets. These findings suggest operational efficiency in production and distribution but point to weaknesses in strategic alignment and supply assurance.

**KPI Classification and Gap Identification.** Disaggregated analysis based on the SCOR model shows that Deliver (8.280), Make (8.258), and Return (8.025) achieved green-category performance, while Source (7.758) and Plan (7.520) remained in yellow. This imbalance points to inefficiencies in procurement, land use, and production planning. Out of 38 validated KPIs, 30 (78.9%) were green, 6 (15.8%) yellow, and 2 (5.3%) red. Red-category KPIs—namely, the percentage of harvested dry grain meeting quality standards (P1) and percentage of achieved planted area (S4)—signal persistent structural constraints related to climate adaptation and land efficiency. Yellow-category KPIs reflected gaps in sales targets, delivery lead times, supplier response times, manpower adequacy, and pricing alignment. These results are summarized in Table 1.

**Table 1.** KPI classification by Traffic Light System

| Traffic Light Category | KPI Code | KPI Description | Number of KPIs | Percentage (%) |
|---|---|---|---|---|
| **Green (≥85%)** | — | KPIs achieving >85% of target performance across Plan, Source, Make, Deliver, and Return perspectives | 30 | 78.9 |
| **Yellow (70–84.9%)** | P3 | Percentage of raw material sales meeting marketing targets | 6 | 15.8 |
| **Red (<70%)** | P1 | Percentage of harvested dry grain meeting quality standards | 2 | 5.3 |
| **Total** | | | 38 | 100.0 |

The distribution of KPI categories is further visualized in Figure 1, which shows the radar plot of underperforming KPIs in the yellow and red zones. Both clearly highlight that strengthening planning and procurement is essential to elevating overall performance.

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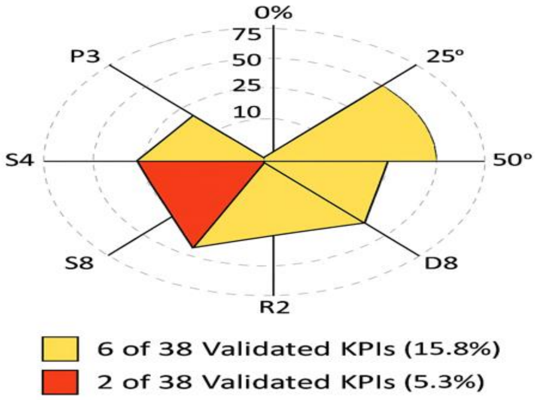


**Figure 1.** Radar Plot of Underperforming KPIs (Yellow & Red)

**Table 2.** Supply chain partnership between the Muara Belida farmers group association and Buyung Poetra Sembada Inc.: KPIs for the red and yellow categories

| Category | Code | KPI's |
|---|---|---|
| Red's | P1 | The percentage of harvested dry grain that was obtained from the Muara Belida farmers group association, in coordination with Buyung Poetra Sembada Inc., was suitable in comparison to the quantity that was anticipated. |
| | S4 | Percentage of achieved planted area at the Muara Belida farmers group association that is in compliance with the goal set by Buyung Poetra Sembada Inc. |
| Yellow's | P3 | Percentage of sales of raw materials from the Muara Belida farmers group association that were in compliance with the marketing goal set by Buyung Poetra Sembada. Inc. |
| | S8 | The interval since the supplier, the Muara Belida farmers group association, sent the raw materials demanded by Buyung Poetra Sembada. Inc. |
| | M8 | The value of the number of employees in Buyung Poetra Sembada Inc. production unit |
| | D4 | The duration required to plan an expedition-style mode of transportation between the Muara Belida farmers group association and Buyung Poetra Sembada Inc. |
| | D8 | Buyung Poetra Sembada Inc.'s average selling price for raw rice from the Muara Belida farmers group association. |
| | R2 | Percent of substandard rice raw materials replaced by fresh, high-quality ones by the Muara Belida farmers group association for Buyung Poetra Sembada Inc. |

The Root Cause Analysis (RCA) identified nine key drivers of underperformance, including limited adaptation to climate change, small land size, suboptimal farming practices, weak quality control, and inadequate training. These findings resonate with previous research on South Sumatra's agribusiness sector, which also points to farmer vulnerability to climate variability and structural weaknesses in upstream supplier networks (Agustina et al., 2019; Andhika et al., 2023). As shown in Table 2, which lists the KPIs in the red and yellow categories. The performance indicators in the yellow and red categories both need to be improved. Although their

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performance is significantly below the target set in the collaboration between the Muara Belida farmers group association and Buyung Poetra Sembada Inc. in South Sumatra, Indonesia, performance indicators that are in the red category must be given priority in their corrective actions.

Table 3, which presents the nine root causes, the combination of biophysical constraints and institutional shortcomings explains why the SCPI remains moderate despite relatively strong downstream performance. The RCA model can make it easier to track the variables that affect performance (Boipelo & Alexander, 2025). In the supply chain integration between the Muara Belida farmers group association and Buyung Poetra Sembada Inc., it was discovered from the evaluation results that nine root causes of KPI performance were not accomplished, which were in the red and yellow categories.

**Table 3.** Sources of supply chain integration issues between Buyung Poetra Sembada Inc. and the Muara Belida farmers group association

| No | The Cause of the issue | Perspective on Supply Chain Integration |
|---|---|---|
| 1. | Members of the Muara Belida farmers group association do not adapt their lowland swamp rice farming to climate change. | P1, P3 |
| 2. | The size of the rice fields in the *lebak*-swamp is smaller than that of the Muara Belida farmers group association and the few farmers that wish to work with Buyung Poetra Sembada Inc. | S4, D4 |
| 3. | The Muara Belida farmers group association members use technology and farming practices improperly. | S8, D8 |
| 4. | Choosing or inspecting *lebak*-swamp rice fields' raw materials from Muara Belida farmers group association members improperly. | R2, M8 |

Furthermore, based on Table 3, a number of recommendations for improvement will be derived from each of these fundamental reasons. The following advice can be applied to enhance performance in supply chain integration between the Buyung Poetra Sembada Inc. and the Muara Belida farmers group association:

First, members of the Muara Belida farmers group association receive ongoing guidance and education from the Buyung Poetra Sembada Inc. team on how to read the climate by observing natural indications. Second, under the lowland swamp farming method, the members of the Muara Belida farmers' group association must employ high-yielding rice cultivars that are more climate change-resistant. Third, the Buyung Poetra Sembada Inc. The team will educate the Muara Belida farmers group association about the integrated planting calendar, adaptation strategies, and climate change mitigation measures in the agricultural sector. Fourth, Buyung Poetra Sembada Inc. and the Muara Belida farmers group association have a written agreement outlining the specifics of the sale and purchase of gathered produce.

Fifth, using modern equipment technology to make it easier for Muara Belida farmers group association members to cultivate and harvest rice. Sixth, Buyung Poetra Sembada Inc. is required to provide training to enhance the knowledge and expertise of the Muara Belida farmers group association members. Seventh, educate the Muara Belida farmers group association members about the best forecasting technique for estimating the level of demand for rice raw materials. Eighth, the Muara Belida farmers group association members are more

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concerned with the free market and government subsidies while implementing the *lebak*-swamp rice farming pattern. In the ninth and last phase, Buyung Poetra Sembada Inc. payment administration system will be fixed by allocating the proper money for payments in coordination with the Muara Belida farmers group association members.

The results of root cause analysis of KPIs that are in the yellow and red categories are shown in Table 3. This analysis is important to identify the main factors causing poor performance from various SCOR perspectives, such as planning, sourcing, production, delivery, and return. As summarized in Table 3, the supply chain risks are categorized into internal and external factors that may affect overall performance. Based on these root causes, a number of recommendations for improvement can be derived. As presented in Table 4, the proposed improvement strategies are aligned with the identified issues and are intended to enhance the effectiveness of supply chain integration between Buyung Poetra Sembada Inc. and the Muara Belida farmers group association. By understanding the root cause of each KPI, improvements to supply chain management strategies can be done in a more targeted manner.

**Table 4.** Root Cause Analysis for KPIs in Yellow and Red Categories

| KPI Code | KPI Description | Root Cause(s) | SCOR Perspectives Affected |
|---|---|---|---|
| **P1** | Percentage of harvested dry grain meeting quality standards | Farmers not adapting lowland swamp rice farming to climate change; improper raw material inspection | Plan |
| **S4** | Percentage of achieved planted area | Limited size of lebak-swamp rice fields; low farmer participation | Source |
| **P3** | Percentage of sales of raw materials meeting marketing targets | Lack of climate-adaptive planting schedules; inadequate market forecasting | Plan |
| **S8** | Supplier response time for fulfilling raw material requests | Improper use of technology; outdated farming practices | Source |
| **M8** | Adequacy of manpower in the production unit | Insufficient skills/training of workers | Make |
| **D4** | Delivery lead time between MBFGA and BPS | Limited transportation planning capacity | Deliver |
| **D8** | Alignment of average selling price for raw rice with agreed pricing | Poor market price monitoring; weak negotiation mechanisms | Deliver |
| **R2** | Percentage of substandard rice replaced with high-quality rice | Improper quality control and inspection procedures | Return |

Value-Added Analysis and Improvement Simulation. Using the Hayami method, the average value-added was Rice = 21.4% (moderate), Maize = 18.7% (moderate), and Horticulture = 35.6% (upper moderate). Overall, the average value-added reached 28.5%, indicating moderate upgrading potential within the Muara Belida food estate. This suggests that while processing and downstream integration already generate

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tangible benefits, there remains significant room to strengthen upstream efficiency and market linkages.

Complementing this, scenario modelling indicated that targeted improvements of 15% in red-category KPIs (P1 and S4) would elevate the overall SCPI score from 7.892 to above 8.2, moving the system into the green category. The greatest performance gains are expected in the Plan and Source perspectives, underscoring the critical role of improved land use, climate-adaptive farming practices, and stronger procurement coordination.

As presented in Table 4, the recommended improvement strategies provide concrete actions to address the identified root causes and ensure that operational weaknesses in the rice supply chain can be systematically corrected. These strategies form the basis for designing interventions that are both practical and measurable. To further illustrate the structure of the rice supply chain and how these improvements can be implemented in practice, Figure 2 presents the infographic of value addition and farmer integration.

The distribution of the main commodities of farmers in South Sumatra as well as the level of integration of farmers can be seen in **Figure 2.** The pie chart shows that horticultural commodities dominate with a portion of 35.6%, followed by rice (21.4%) and corn (18.7%). Meanwhile, the bar chart on the right side depicts the Farmer Integration Index, which reaches 3.9. This value confirms that the integration of farmers in the agribusiness supply chain is relatively high, although there is still room for improvement, especially in strengthening marketing networks and logistics support.

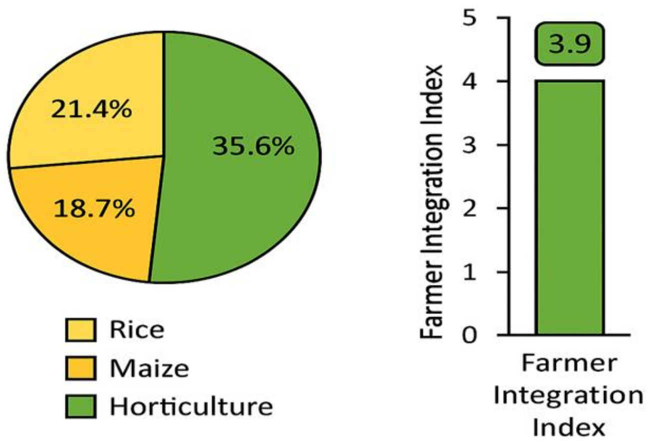


**Figure 2.** Infographic of Value Addition & Farmer Integration

The measurement results showed that the Supply Chain Performance Index (SCPI) of 7.892 was in the yellow category, indicating that SCM integration in Muara Belida remains moderate. Strong performance in Deliver, Make, and Return reflects efficiency in downstream processes, while weaknesses in Plan and Source highlight upstream bottlenecks. Red KPIs (e.g., climate adaptation and land efficiency) and yellow KPIs (e.g., procurement, labor, logistics) confirm persistent structural gaps. Moderate added value (28.5%) further indicates limited transformation of production into higher market value, consistent with earlier findings on swamp-based agribusiness in South Sumatra (Agustina et al., 2019; Andhika et al., 2023).

These results align with international literature emphasizing upstream coordination in SCM. Evidence from Vietnam (digital traceability), Thailand (cooperative models), and Brazil (logistics integration) illustrates similar challenges, while Sub-Saharan Africa also demonstrates that fragmented supply chains reduce efficiency (Nguyen et al., 2021;

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de Souza et al., 2022; Nchanji et al., 2021). Comparable studies in Indonesia highlight similar governance and coordination gaps in food estates (Islah et al., 2021; Purwanto & Siregar, 2023).

The policy implication is that achieving planting targets alone is insufficient to secure long-term food resilience. Strengthening the Plan and Source dimensions—through formal contracts, climate-adaptive practices, digital platforms, and cooperative-based procurement—is essential. These measures are consistent with Indonesia's RPJMN 2020–2024, Presidential Regulation No. 59/2020, and SDG 2 (*Zero Hunger*).

Practically, farmers are encouraged to adopt climate-resilient varieties, mechanization, and planting calendars, while collective procurement via Gapoktan/BUMP can reduce input costs and increase bargaining power. Policymakers should invest in rural infrastructure, develop SCM digital monitoring systems, and promote agro-processing and branding to enhance added value (Yunita et al., 2024; Hotden et al., 2021).

This study has limitations, including a relatively small and non-random sample and reliance on self-reported data. Moreover, the SCOR–ANP–OMAX–Hayami framework captures operational efficiency but not socio-cultural or institutional dynamics. Future studies should expand across multiple food estate locations, adopt mixed-methods approaches, and integrate emerging technologies such as IoT, blockchain traceability, and system dynamics modeling (Ashutosh et al., 2025). Cross-ecosystem comparative and ethnographic supply chain studies would further enrich insights.

In sum, the findings confirm that swamp-based food estates cannot rely solely on planting targets. Systemic SCM integration—from planning and procurement to production and distribution—is crucial for transforming them into resilient agro-industrial clusters, enhancing farmer competitiveness, and directly contributing to Indonesia's food security and sovereignty.

## CONCLUSION

This study addressed the performance, barriers, and contributions of supply chain management (SCM) integration in the Muara Belida food estate. The results indicate that the overall Supply Chain Performance Index (SCPI) reached 7.892 (yellow category), reflecting moderate performance. Strengths were identified in Deliver, Make, and Return, while persistent bottlenecks in Plan and Source revealed upstream challenges such as land constraints, weak climate adaptation, limited technology adoption, and insufficient farmer capacity. The value-added analysis (28.5% on average) and scenario modeling further demonstrated that targeted improvements of 15% in underperforming KPIs could elevate the system into the green category, providing evidence that SCM integration improves efficiency, adds value, and builds resilience in swamp-based food estates despite persistent upstream bottlenecks.

The findings imply that food estate development cannot rely solely on planting and production targets but requires systemic SCM integration across planning, sourcing, production, and distribution. Policymakers should prioritize capacity building, technology adoption, and institutional support to address upstream challenges, while researchers are encouraged to expand analyses across multiple sites, integrate socio-cultural dimensions, and explore emerging tools such as IoT-based KPI monitoring, blockchain traceability, and system dynamics modeling. Such efforts would not only strengthen farmer competitiveness but also accelerate the transformation of food estates into resilient agro-industrial clusters that contribute directly to Indonesia's long-term food security and sovereignty. Systemic SCM integration is essential to transform food estates into resilient agro-industrial clusters that secure Indonesia's long-term food sovereignty.

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