



Strategy for Improving Rice Agroindustry Production Processes Based on Green Value Stream Mapping

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Abstract

The rice agroindustry faces challenges due to high inefficiency and negative environmental impacts from excessive resource use. This study aims to improve production processes using Green Value Stream Mapping (GVSM) to reduce non-value-added activities and optimize natural resource usage. The research involves literature review, field observation, interviews, brainstorming, and expert opinions. The production process from seeds to distribution consumes 265 kWh of energy and 8 million liters of water, generates 10,532 kg of waste, and impacts 1.2 hectares of biodiversity. The study confirms that the GVSM strategy enhances operational efficiency and contributes to broader environmental sustainability. The research provides practical guidelines for rice agroindustry companies to implement more environmentally friendly and efficient production practices.

Introduction

The Indonesian rice agroindustry is crucial for meeting the food needs of the Indonesian population, but the sector faces increasing challenges due to the high use of energy, water, and raw materials, which negatively impact the environment (Efendi, 2016). Traditional production practices are inefficient and generate excessive waste, necessitating innovative approaches to optimize production efficiency and minimize environmental impact (Yudiarini, 2011). Green Value Stream Mapping (GVSM) is a method developed to enhance production efficiency and environmental sustainability in the manufacturing sector (Ikatrinasari et al., 2018; Garza-Reyes et al., 2018; Edtmayr et al., 2016; Wiryawan & Djana, 2020). It focuses on identifying and reducing waste in the production process, reducing energy consumption, water, and carbon emissions. GVSM allows companies to visualize material, energy, and information flow, identifying areas for environmental impact reduction without sacrificing productivity (Choudhary et al., 2019; Batwara et al., 2024; Asrol & Purba, 2021; Fontoura et al., 2023).

In the context of the rice agroindustry, the implementation of GVSM can provide a strategic solution to improve production performance while reducing the environmental footprint (Chernysh et al., 2024; Banerjee et al., 2023). Through the implementation of GVSM, the rice production process can be evaluated more comprehensively, including energy use at each stage of the process, emissions produced, and the efficiency of water and material use. Several previous studies have shown that the implementation of GVSM can result in a significant reduction in energy consumption, a reduction in carbon emissions, and water use efficiency in the production process (Budihardjo & Hadipuro, 2022; Choudhary et al., 2019; Chen et al., 2024; Faulkner & Badurdeen, 2014).

Research on improving efficiency and sustainability in the manufacturing industry has undergone significant development in recent decades, especially through the application of lean manufacturing methodologies. One of the most widely used methods is Value Stream Mapping

(VSM), which aims to identify and reduce waste in the production process (Zhu et al., 2020; De Steur et al., 2016; Tyagi et al., 2015). However, traditional VSM methods focus more on the aspects of time and cost efficiency, without paying enough attention to the environmental impact resulting from the production process. In response to the need for more sustainable production, Green Value Stream Mapping (GVSM) was introduced as a development of traditional VSM. GVSM not only identifies wasted time and money, but also prioritizes reducing environmental impacts, including carbon emissions, energy, water and material use. With this approach, GVSM provides a holistic solution to improve operational efficiency while reducing the environmental footprint of the production process (Andreazza de Freitas et al., 2024; Jamil et al., 2020).

Several studies have shown the effectiveness of GVSM in various sectors, such as manufacturing, automotive, and food. For example, revealed that the application of GVSM in the manufacturing sector is able to significantly reduce energy consumption and carbon emissions without sacrificing productivity (Rhyner et al., 2017). In the agro-industry sector, especially rice milling, the implementation of GVSM is still relatively new but shows great potential. In Indonesia reveals that GVSM is able to reduce electricity consumption by up to 51.4%, LPG use by up to 24.42%, and water use by up to 60%, without reducing productivity (Budihardjo & Hadipuro, 2022). In the future, GVSM can also be integrated with broader sustainability concepts such as the circular economy and Industry 4.0 to improve efficiency and sustainability in more complex industries (Bag & Pretorius, 2022; Elemure et al., 2023; Faulkner & Badurdeen, 2014).

On the other hand, there is an urgent need to switch to greener and more sustainable production practices, and a strategy to improve the production process of the rice agro-industry based on GVSM is a relevant step. This study aims to analyze the mapping of value streams using GVSM of the rice agroindustry and formulate strategies to improve the production process. It is hoped that the results of the research can fill the gap in GVSM knowledge in the context of the rice agroindustry, with the hope of increasing efficiency, reducing waste, and increasing the sustainability of the rice production process.

Methods

Stages of research

This study uses the Green Value Stream Mapping (GVSM) approach to identify and eliminate waste and reduce environmental impacts in the rice production process. The research stage begins with a literature review to understand the concept of rice production, Value Stream Mapping (VSM) methodology, and GVSM principles. The results of this literature review were used to build a conceptual framework that connects the rice production process with waste identification and GVSM-based remediation strategies.

Furthermore, research was conducted through case studies on several rice agroindustries to collect data on the production process, including material flow, cycle time, inventory, and resource use. This data is used to compile a Value Stream Map that reflects the actual production process and identifies potential improvements with the GVSM approach. The analysis is carried out to identify waste in the production process. GVSM-based remediation strategies are then developed to reduce waste, taking into account aspects of sustainability and environmental impact, such as operational efficiency, resource use, green technology, and product distribution.

Data Collection Techniques

This study uses primary data. Primary data was obtained through field observations, interviews, and brainstorming with experts.

Data collection techniques are carried out through: (1). Field observation: Data was obtained through purposive sampling in the rice agroindustry that met the research criteria. (2). Interview: Conducted to obtain direct information from agroindustry stakeholders and confirm the results of the research. And, (3). Brainstorming and expert opinions: In-depth discussions with experts in the field of rice agroindustry through purposive sampling. In this study, researchers used 3 respondents from Micro, Small and Medium Enterprises (MSMEs) in the rice agroindustry sector selected by purposive sampling with the criteria that these MSMEs have been running for more than 5 years with rice production of 20 tons.

The research was conducted in several rice agroindustry centers in Agam Regency, West Sumatra Province, Indonesia. Interviews and brainstorming are conducted face-to-face and online. The data was processed at the Laboratory of Systems Engineering and Agricultural Industrial Engineering, Department of Agricultural Industrial Technology. The research took place from April to June 2024.

Data Analysis Techniques

Green Value Stream Mapping

The GVSM analysis is carried out with the following steps: (1). Identifying seven waste constituents (energy, water, materials, waste, transportation, emissions, biodiversity). (2). Create a current-state map and measure waste. And, (3). Develop a future-state map along with waste elimination steps. The software used in making GVSM includes: (1) Excel to analyze data, (2) Draw.io, and (3) Excalidraw to draw the current state green value stream mapping.

Formulation of Improvement Strategy

Improvement strategies are developed using SWOT analysis, which involves identifying strengths, weaknesses, opportunities, and threats. This approach helps formulate effective strategies to improve efficiency and sustainability in the rice agro-industry production process.

Results and Discussion

Analysis Green Value Stream Mapping (GVSM)

VSM has become a method that is often used to measure the level of productivity of the production process in companies, as time goes by the company's awareness of the importance of regulating the impact on the environment is getting higher, therefore to accommodate the need to measure environmental impact on the production process, GVSM is used, the similarity with VSM is that this method both provide visualization related to opportunities for improvement in the production process, It's just that GVSM is considered more advanced because in addition to having a focus on finance, it also has the opportunity to make improvements to environmental impact problems or reduce waste that has a bad impact on the environment (Patten, 2010).

The rice production process shown in the Green Value Stream Mapping (GVSM) starts from management at the farmer group office, where seeds are prepared with a requirement of 30 kg per hectare using the transplant method. These seeds are then transported using light trucks to small-scale farmland, with a distance of 10 km and producing CO₂ emissions of 2.5 kg. The process of planting rice fields involves the use of energy of 35 kWh and requires a large amount of water, namely 8×10^6 liters. This stage also requires 440 kg of material and produces 7,500

kg of waste, with transportation covering a distance of 30 km and carbon emissions of 700 kg CO₂. The impact on biodiversity from this planting stage reaches 1 hectare.

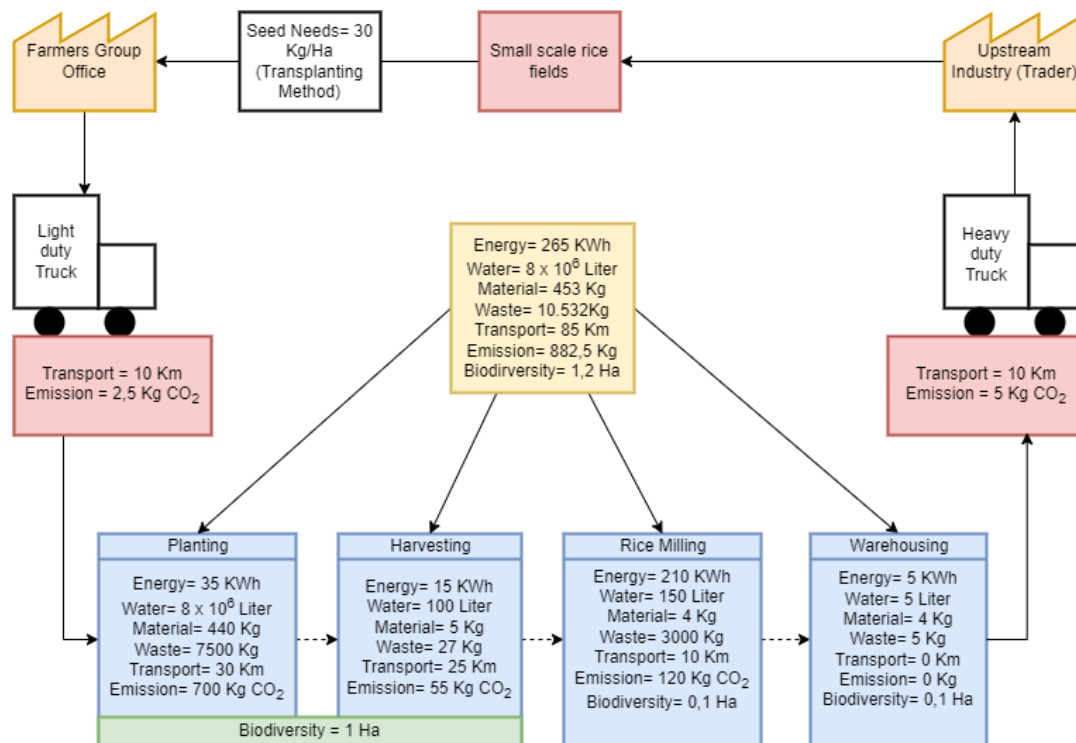


Figure 1. Current state green value stream mapping

After the planting process, rice is harvested with an energy consumption of 15 kWh and much less water use, namely 100 liters. The material needed in the harvest stage is 5 kg, and the waste produced is 27 kg. The transportation needed in this stage covers a distance of 25 km, with carbon emissions reaching 55 kg of CO₂. This harvesting process has an impact on biodiversity of 0.1 hectares. Furthermore, the rice is ground in the rice milling stage, where the energy consumed is 210 kWh with 150 liters of water. This stage requires 4 kg of material, while the waste produced reaches 3,000 kg. Transportation in the milling process travels a distance of 10 km and produces emissions of 120 kg of CO₂, as well as an impact on biodiversity of 0.1 hectares.

After milling, the rice is stored in a warehouse with an energy consumption of 5 kWh and 5 liters of water. This stage requires 4 kg of material and produces 6 kg of waste. The transportation process to the warehouse covers a distance of 5 km and produces emissions of 10 kg of CO₂, with an impact on biodiversity of 0.1 hectares. In the final stage, these products are sent to the upstream industry or traders, where transportation is carried out using heavy trucks with a distance of 10 km and carbon emissions of 5 kg CO₂.

Overall, this production chain consumes 265 kWh of energy and uses 8 × 10⁶ liters of water. The amount of waste produced from all stages reached 10,532 kg, while carbon emissions from transportation reached 882.5 kg CO₂. This process also had an impact on biodiversity of 1.2 hectares. This GVSM reveals various points where energy efficiency, waste management, and carbon emission reduction can be optimized, as well as the importance of maintaining biodiversity in every stage of production. The strategic approach is to optimize GVSM's efficiency and sustainability in production, leveraging regulatory support and environmentally friendly consumer trends. Companies must address internal weaknesses like resistance to

change and implementation complexity through training, capacity building, and a phased approach, while mitigating unexpected costs and technological changes.

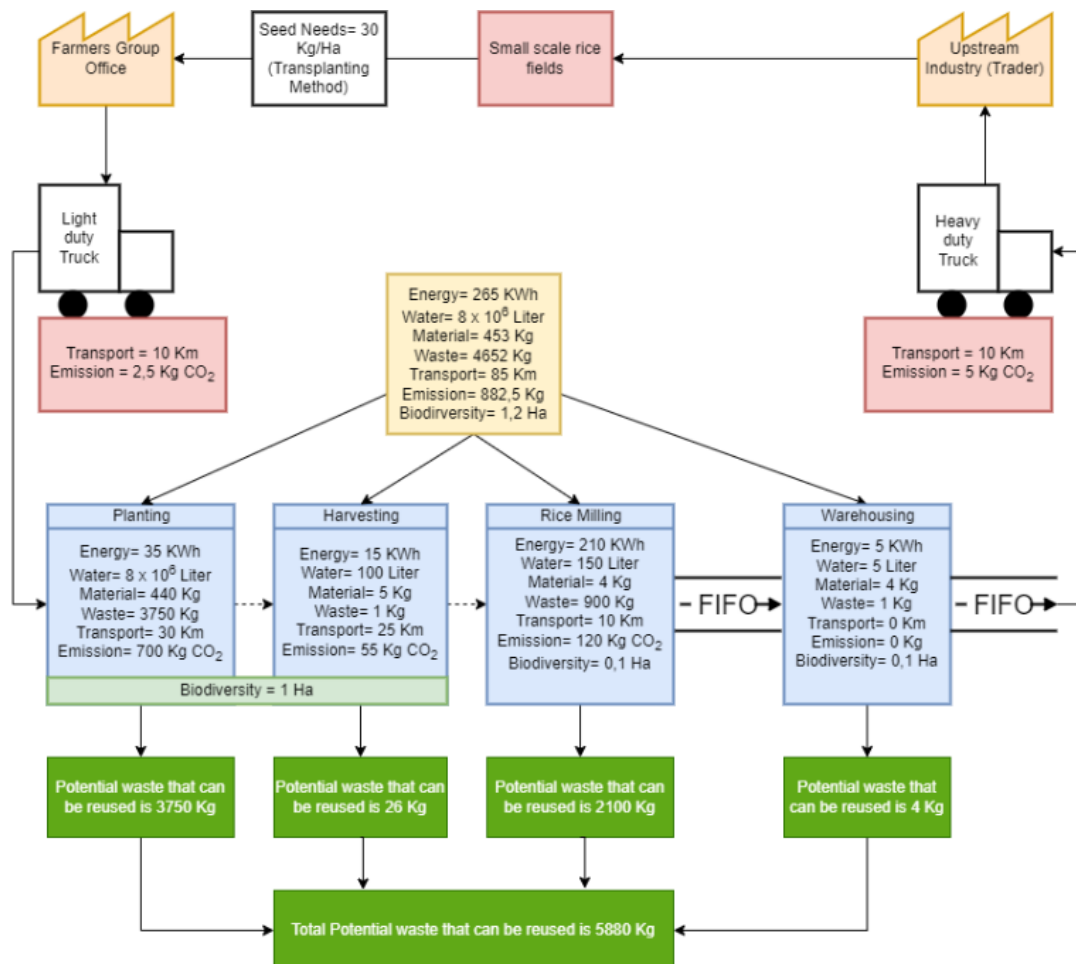


Figure 2. Future state green value stream mapping

The total potential waste that can be reused in the rice agroindustrial process reaches 5880 kg, which is spread across various stages of the supply chain. The management of this waste potential requires an integrated strategy at every stage, from planting to storage. At the planting stage, there is 3750 kg of waste that can be reused. This waste mostly comes from the rest of organic matter that can be processed into compost or fertilizer to improve soil quality in the next production cycle. This utilization not only reduces waste discarded, but also contributes to improving the overall sustainability of agricultural processes (Fercoq et al., 2016).

Furthermore, at the harvest stage, although the waste produced is relatively small, which is only 26 kg, it still has the potential to be reused, for example by processing plant residues into animal feed or raw materials for other industries. At the rice milling stage, there is a much greater potential for waste, namely 2100 kg, which can be utilized, for example by utilizing rice husks for bioenergy production or as raw materials for making environmentally friendly products such as particle board or insulation materials. Waste management at this stage is very important because its significant amount can have a major impact on total waste reduction.

The last stage, namely warehousing, produces a relatively small amount of waste, amounting to 4 kg. However, waste from this stage can also be utilized with approaches such as recycling packaging materials or leftover products that may be damaged during the storage process. This comprehensive waste management strategy across the supply chain has the potential not only

to reduce waste, but also to improve resource efficiency as well as create new economic opportunities through the utilization of waste that was previously considered useless. The implementation of the circular economy concept in the rice agroindustry can strengthen production sustainability and extend the life cycle of materials, ultimately contributing to environmental and social sustainability (Geissdoerfer et al., 2017).

The strategic approach is to maximize GVSM's efficiency and sustainability in production, leveraging regulatory support and environmentally friendly consumer trends. Addressing internal weaknesses, training, capacity building, and a phased approach mitigates potential implementation costs and technological changes.

Rice Agroindustry Development Strategy

Based on Green Value Stream Mapping (GVSM) which shows the rice production process from the farmer group office to the storage stage in the warehouse, SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis can be used to develop a comprehensive strategy for the development of the rice agroindustry. Here is a development strategy based on a SWOT analysis.

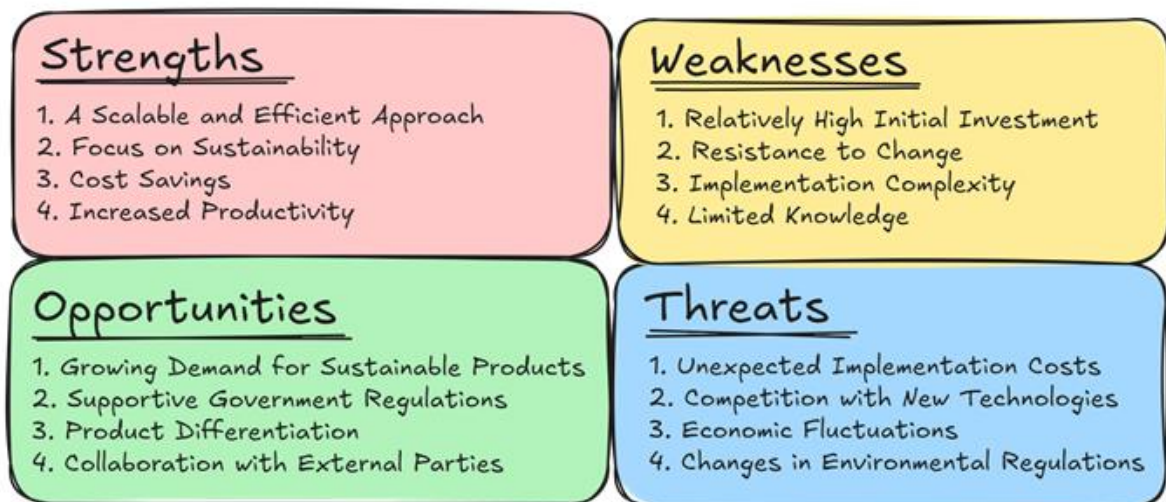


Figure 3. SWOT Analysis

Strengths

Scalable and Efficient Approach

The rice agroindustry can increase production scale without significantly increasing operational costs by optimizing technology and mechanization, such as energy-efficient milling equipment and smart irrigation systems.

Focus on Sustainability

The agroindustry can win the market by focusing on sustainability in rice production, reducing chemical use, utilizing renewable energy, and minimizing carbon emissions through environmentally friendly technologies.

Cost Savings

Efficient processes, digitalization, and waste management can lead to cost savings in water, energy, supply chain optimization, and waste conversion into valuable materials.

Increased Productivity

With better efficiency, productivity can increase. The rice agroindustry can harness this power by adopting new technologies to speed up production processes, increase yields, and reduce downtime due to operational issues.

Weaknesses

Relatively High Initial Investment

The rice agroindustry must address initial investment challenges by utilizing government financing, investors, public-private partnerships, grant assistance, and tax incentives for sustainability-focused investments.

Resistance to Change

Traditional workers may resist agro-industry changes, necessitating training and education programs to promote organizational culture change and adopt new technologies, emphasizing sustainability and long-term benefits.

Implementation Complexity

Implementing new technologies in the agroindustry can be simplified by using a phased approach and consulting experienced partners to focus on the most impactful areas.

Limited Knowledge

Lack of knowledge about latest technologies and eco-friendly practices among farmers and workers requires increased human resource capacity through intensive training, skill development programs, and partnerships with research institutions.

Opportunities

Growing Demand for Sustainable Products

The rice agroindustry can capitalize on growing consumer awareness of sustainable products by offering organic rice and strengthening its sustainable product branding.

Supportive Government Regulations

The government is promoting sustainable agricultural practices through subsidies and tax incentives, aiming to accelerate the transition to green technologies in the agro-industry.

Product Differentiation

The rice agroindustry can diversify its product range, including health-focused brown, black, organic, and fortified rice, thereby enhancing competitiveness and market expansion.

Collaboration with External Parties

Collaborating with research institutions, universities, and technology companies can enhance production efficiency and sustainability, while NGOs and environmental agencies can help obtain internationally recognized sustainability certifications.

Threats

Unexpected Implementation Costs

Unexpected costs during new technology implementation pose a threat to the agroindustry. To mitigate this, the industry should establish contingency plans, manage projects effectively, and conduct thorough feasibility studies.

Competition with New Technologies

The rice agroindustry must innovate and stay competitive in the ever-evolving world by monitoring the latest technology trends to stay ahead of the competition.

Economic Fluctuations

Economic changes, like energy and fuel price fluctuations, can impact production costs, necessitating the agroindustry to transition to sustainable, stable renewable energy sources.

Changes in Environmental Regulations

The rice agroindustry must adapt to stringent environmental regulations by being proactive and implementing higher production standards to ensure compliance with future changes.

With the above SWOT analysis, the rice agroindustry can develop effective strategies to improve efficiency, sustainability, and competitiveness in a market that is increasingly concerned about the environment and sustainable products.



Figure 4. SWOT Strategy

After conducting a SWOT analysis, a strategy for the development of the rice agro-industry is formulated through a SWOT strategy which is described from four combinations of SWOT elements:

Strengths - Opportunities (SO)

This strategy leverages internal strengths to take advantage of the opportunities that exist in the market. Some strategies that can be applied are:

Optimization of Efficiency and Product Differentiation

The rice agroindustry can improve production efficiency through new technologies and best practices that are more environmentally friendly. In addition, they can create product differentiation. According to Han, et al. (1998) linear product differentiation on product marketing performance, in their research that product differentiation has a positive and significant impact on marketing performance through the allocation of dynamic technological resources. His research shows that the success of a product needs to adopt appropriate technology in order to produce quality products and optimize the efficiency of rice agro-industry production (Han et al., 1998). An example of product differentiation in the rice

agroindustry is such as organic rice or healthy rice with additional nutritional value, which will attract certain consumer segments who care about health and sustainability. Product differentiation can run well if it is able to display products that have different values (*Value Preposition*) against competitor products (Rangotwat, 2018).

Utilization of Regulatory Support

The government encourages sustainable agriculture and environmentally friendly practices by providing incentives or supportive regulations. Agroindustries must take advantage of this opportunity to obtain financial assistance or tax benefits, as well as comply with regulations to remain competitive in the market. In the research of Dewi et al. (2023), it was found that rice agroindustry actors can influence policy-making by the government. Therefore, in formulating policies, the government usually conducts hearings with rice agro-industry players so that the policies or regulations that are prepared can accommodate all interests fairly.

Cooperation with External Parties

Working with research institutions, universities, and technology companies can open up access to new technologies, resources, and innovations that can improve efficiency and sustainability. Cooperation with external parties can be maximized by forming institutions in the rice agroindustry sector, according to Nuraini, et al. (2016) that institutions are an important factor in regulating the relationship between rice agroindustry actors and related parties so that they are able to open access to the latest technology, resources and innovations (Nuraini et al., 2016). This collaboration can also help in the marketing of innovative and environmentally friendly rice products.

Weaknesses - Opportunities (WO)

Strategi ini difokuskan pada upaya untuk memperbaiki kelemahan dengan memanfaatkan peluang eksternal. Beberapa strategi yang dapat diterapkan adalah:

Employee Training and Capacity Building

One of the drawbacks is the lack of knowledge and expertise in implementing new technologies. Therefore, training and capacity building of human resources is essential to ensure that the rice agroindustry can successfully adopt new practices and technologies (Kosdianti et al., 2021).

Long-Term Investment with External Support

As high initial investment is an obstacle, the agroindustry must seek external partners for financial support, such as through private investors, governments, or international grants that support sustainability initiatives. These investments should be directed towards the long-term implementation of technologies that can improve efficiency and sustainability (Patriyansyah et al., 2023).

Weaknesses - Threats (WT)

This strategy is designed to minimize weaknesses while addressing existing threats. Some strategies that can be applied are:

Mature Financial Risk Management

To overcome the threat of unexpected costs in implementation, the agro-industry must have a good financial risk management system (Purbaningsih et al., 2023). This includes setting up a reserve fund for unexpected expenses and conducting a risk analysis before starting a new project.

Pilot Project Approach

Given the complexity of implementing new technologies, a pilot project approach can help minimize risks (Winarno et al., 2024). By starting small, companies can evaluate the impact of new technologies before extending their use to the entire production process. It can also reduce the risk of greater failure.

Strengths - Threats (ST)

This strategy uses existing strengths to deal with external threats. Some strategies that can be applied are:

Risk Mitigation of Implementation Costs with a Phased Approach

To overcome the threat of high costs in the application of new technologies, agro-industry can implement technologies gradually. By prioritizing the areas that have the most significant impact first, companies can manage costs more efficiently while ensuring increased productivity and sustainability (Pakdeenarong & Hengsadeeikul, 2020).

Adaptation to Technological Changes

By using the power of efficiency and scalability, the agro-industry can adapt faster to technological changes. Adopting the latest and sustainable technologies will make them more flexible and resilient in the face of challenges from new competitors or changes in the technology market (Hussain et al., 2020).

Implementing a SWOT strategy can optimize the rice agroindustry's strengths, opportunities, and weaknesses, enhancing its long-term competitiveness and promoting sustainable growth.

Conclusion

This study shows that Green Value Stream Mapping (GVSM) has a significant impact on production efficiency and sustainability in rice agro-industry. It optimizes energy efficiency, waste management, and carbon emission reduction, minimizing energy consumption, water use, waste, and carbon emissions. Some of the key findings underlying this conclusion are the production process from seeds are prepared, planting, harvest, milling, warehouse stage, and last distribution stage consumed 265 kWh of energy and 8 million liters of water, generated a total of 10,532 kg of waste, 882.5 kg of CO₂ from transportation, and impacted 1.2 hectares of biodiversity. The total potential waste that can be reused in the rice agroindustrial process reaches 5880 kg, which is spread across various stages of the supply chain. At the planting stage 3750kg, the harvest stage 26kg, the rice milling 2100kg, and the warehousing 4kg of waste that can be reused. The rice agro-industry's development strategy emphasizes efficiency, sustainability, and cost savings. Opportunities from market trends, government regulations, and external collaboration are crucial for competitiveness.

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