



Value-Added Processing Analysis for the Cassava Industry toward a Green Economy: A BPMN and VSM Study

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Abstract. The increasing environmental pollution caused by synthetic plastics highlights the urgent need for sustainable, nature-based alternatives. However, challenges persist due to the limited availability and relatively high cost of eco-friendly raw materials. One promising option is the utilization of Indonesia's abundant natural resources, particularly cassava (*Manihot esculenta* Crantz). As a local commodity with high adaptability and low agricultural input requirements, cassava holds significant potential as a raw material for biodegradable plastic production. In addition to plastics, cassava can be transformed into various value-added products such as bioethanol, liquid sugar, and analog rice. This dual role positions cassava as both an environmental and economic solution. The present study seeks to evaluate cassava's industrialization potential by employing Business Process Model and Notation (BPMN) to map the upstream-to-downstream supply chain and Value Stream Mapping (VSM) to identify inefficiencies. The BPMN mapping indicates six main stages in the cassava supply chain: cultivation by farmers, collection, sorting and grading, processing, production and packaging, and distribution to consumers. The VSM analysis further identifies several non-value-added activities that require optimization to improve overall system performance. Importantly, cassava-based biodegradable plastics provide a practical means to reduce synthetic waste and accelerate the shift toward a green economy. Thus, the integrated development of the cassava industry represents a strategic pathway for building sustainable agricultural systems, strengthening local economies, and supporting large-scale adoption of environmentally friendly products to achieve a cleaner future.

Keywords: Sustainable Agriculture, Green Economy, Business Process Model and Notation (BPMN), Value Stream Mapping (VSM), Supply Chain Optimization.

1 Introduction

Environmental pollution caused by the accumulation of synthetic plastic waste has emerged as one of the most pressing global challenges. Petroleum-based plastics are characterized by their non-biodegradable properties, allowing them to persist in the environment for hundreds of years [1][2]. Such waste not only contaminates terrestrial

ecosystems but also pollutes aquatic environments, leading to severe disruptions in marine life and the presence of microplastics in the human body due to fish ingestion [3]. In Indonesia, the use of single-use plastics continues to rise in line with population growth and industrial activities, while recycling rates remain relatively low. According to the Ministry of Environment, Indonesia generates approximately 6,908,524.91 tons of plastic waste annually [4]. This situation exacerbates environmental degradation, poses risks to human health, and undermines ecosystem sustainability.

In response to this crisis, numerous innovations have been introduced to reduce plastic waste, such as recycling and repurposing plastics into value-added products [5]. Moreover, a range of initiatives has been developed to explore environmentally friendly alternatives, among which bioplastics or biodegradable plastics stand out. However, the development of bioplastics often faces challenges related to the sustainable availability of raw materials and high production costs. Common feedstocks

such as corn and potatoes tend to compete with food security needs, thereby raising long-term ethical and economic concerns.

Within the Indonesian context, cassava (*Manihot esculenta* Crantz) presents substantial potential as an alternative solution. As a locally abundant crop with high adaptability to diverse agro-climatic conditions and relatively low agricultural input requirements, cassava represents a strategic resource. Beyond its application as tapioca starch for bioplastic production, cassava can also be processed into value-added derivatives such as bioethanol [6], liquid sugar [7], and analog rice [8]. Utilizing cassava as a raw material for biodegradable plastics offers Indonesia the dual advantage of reducing reliance on synthetic plastics while simultaneously fostering an agriculture-based local economy.

Despite these promising prospects, systematic studies mapping the industrialization of cassava from upstream to downstream remain limited. To ensure effectiveness and efficiency in production, a methodological approach capable of visualizing workflows and identifying non-value-added activities in the supply chain is required. Consequently, this study employs Business Process Model and Notation (BPMN) to comprehensively map business processes, alongside Value Stream Mapping (VSM) to analyze efficiency and identify opportunities for improvement within the production system—particularly in tapioca flour industries as the primary raw material for bioplastics.

Accordingly, the purpose of this research is to evaluate the industrialization potential of cassava as both an environmental solution and a driver of local economic growth through value chain optimization. By applying BPMN for process mapping and VSM for efficiency analysis, this study is expected to contribute to the advancement of more sustainable agricultural and industrial systems in Indonesia.

This research holds significant implications across societal, academic, and governmental domains. From a societal perspective, cassava-based products can deliver tangible benefits in everyday life. In addition to serving as a nutritious food source, cassava has the potential to generate income and improve livelihoods, particularly in cassava-producing regions. Broader utilization of cassava may also strengthen food sovereignty and reduce dependence on imported products. Academically, this study provides a relevant reference that can serve as a foundation for students and researchers

to further develop similar inquiries. It aligns with efforts to enrich scientific literature, particularly concerning innovations in the utilization of local resources for value-added and environmentally friendly products. From a governmental perspective, the findings can serve as a basis for formulating policies that promote local economic development while simultaneously reducing reliance on conventional plastics. Thus, this research contributes not only to enhancing community welfare and advancing scientific knowledge but also to supporting sustainable development agendas aligned with national policy priorities.

Existing literature highlights that the cassava industry in Indonesia comprises several subsystems: production (farmers), post-harvest handling (sorting, soil cleaning, washing, and drying), processing (small- and medium-scale enterprises or factories), as well as distribution and marketing. Cassava business processes are predominantly dominated by micro and small-scale enterprises.

2 Research Methodology

This study employs a descriptive qualitative approach to illustrate the real conditions of cassava farming processes in Nagan Raya, observed on 24 September 2024. The analysis focuses on identifying problems within farmers' business processes. At the national level, supporting data are derived from literature reviews, scholarly articles, and case studies on the cassava industry in Indonesia. Through this approach, the study aims to provide an in-depth description of farming activities, the challenges encountered, and potential improvements that may be implemented.

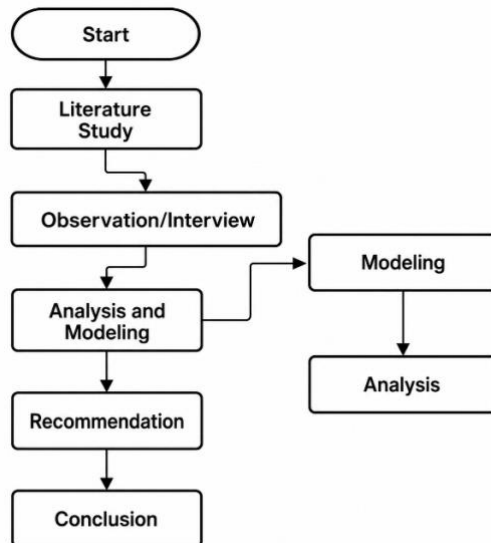


Figure 1. Research Method Framework

3 Research Methodology

Based on the review of literature and articles, it was observed that the typical cassava business process flow in Indonesia consists of several stages, namely land preparation, seed preparation, crop maintenance, harvesting, sorting, distribution to factories or small and medium enterprises (SMEs), washing, peeling, grinding or slicing, and finally packaging.

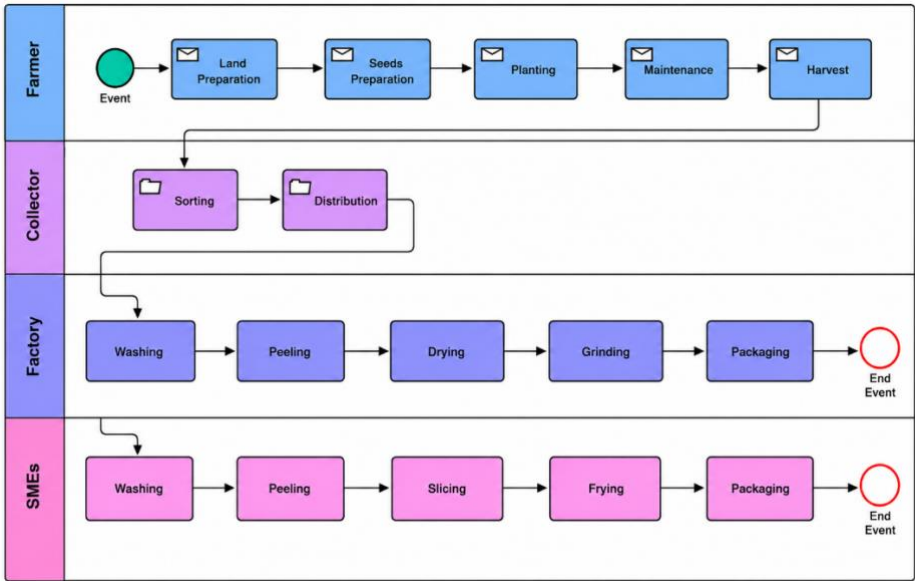


Figure 2. Business Process Modeling from Farmers to Final Products

After conducting interview result identification, the next step is to develop a business process model using Lucidchart. The diagram below illustrates the business process flow in Nagan Raya, which encompasses land preparation, seed preparation, cultivation, harvesting, sorting, and distribution to markets or collectors.

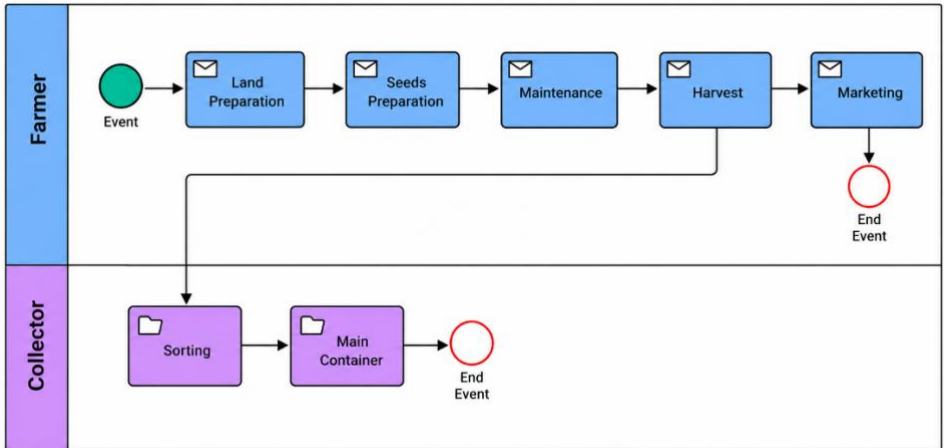


Figure 3. Business Process Modeling from Farmers to Collectors

This condition indicates that although farmers in Nagan Raya possess relatively large land potential, productivity remains low due to limited capital, inadequate technology, and the use of simple planting methods. In addition, the rudimentary distribution system weakens farmers' bargaining power, resulting in low selling prices. As a consequence, cultivation is typically carried out only on a small scale. This is reflected in land preparation practices that are still performed manually, with grass burning used as a natural fertilizer. After planting, fertilization is generally applied only once, which leads to suboptimal harvest outcomes.

Furthermore, the fertilization process reflects under-processing, as a single application of fertilizer does not sufficiently meet the crop's continuous nutrient requirements during its critical growth phases. Consequently, plant growth becomes stunted, leaves turn yellow, and root development remains suboptimal, directly resulting in smaller and less dense cassava yields. Nutrient deficiencies also increase plant susceptibility to pests and diseases, further worsening the situation and reducing the overall yield potential. To address this issue, a more structured fertilization schedule is required, tailored to the crop's nutritional needs at each stage of development, rather than applying fertilizer only once.

3.1. Value Stream Mapping (VSM), Land Preparation Improvement

Land preparation carried out by cassava farmers is generally still conducted manually using traditional tools such as hoes, machetes, or sickles. This process requires a considerable amount of human labor and consumes a significant amount of time. For medium-sized plots, for instance, approximately half to one hectare, the required time may reach five to nine days, depending on land conditions, the number of available laborers, and soil fertility levels. If the land contains dense shrubs or remnants of previous crops, the preparation process takes even longer, as farmers must clear the entire surface before planting. In contrast, the use of tractors reduces the required time to only about 1–2 days [9][10]. This demonstrates a substantial difference in efficiency between traditional manual methods and modern mechanized approaches.

3.2. Fertilization Process Improvement

In Nagan Raya, farmers generally apply fertilizer only once, from the planting stage until harvest. They assume that burning weeds and grasses during land preparation provides sufficient nutrients for the crop. However, the combination of ash from burning and a single fertilization results in suboptimal cassava growth. At harvest, many cassava roots are undersized, which directly affects the sorting stage, as a significant proportion of the yield is deemed unfit for sale to collectors. To address this issue, fertilization should be carried out three to four times throughout the crop cycle in order to achieve optimal yields [11].

3.3. Opportunities

The mapping of cassava agribusiness processes from upstream to downstream in Nagan Raya Regency reveals that adequate processing of harvested cassava is still lacking. Common derivative products of this commodity, such as cassava chips and tapioca flour, are not yet produced locally on either an industrial or small-scale basis. This condition indicates that the majority of cassava is sold in raw form to collectors, without generating added value at the farmer or local enterprise level.

Based on the current condition of cassava farming in Nagan Raya, it is evident that there are significant opportunities that have not been fully utilized. Until now, cassava has primarily been sold in raw form to collectors or local markets, resulting in limited added value for farmers and local entrepreneurs. In fact, cassava is not only valuable as a food source but also holds considerable potential to be processed into high-value products such as bioethanol, liquid sugar, and bioplastics. One of the most promising innovations is the utilization of cassava starch as a raw material for bioplastic production. Bioplastics are environmentally friendly plastics derived from renewable natural resources, in contrast to conventional plastics, which are petroleum-based. The primary advantage of cassava-based bioplastics lies in their biodegradable nature, enabling them to decompose naturally by microorganisms, thus posing less harm to the environment.

Cassava starch contains amylose and amylopectin compounds that serve as natural polymers. With appropriate processing technology, these components can be converted into raw materials for bioplastic production. This potential is highly relevant to the current global context, where plastic pollution has become a pressing concern. Single-use plastic waste continues to accumulate on land and in marine environments, making bioplastics a long-term solution to gradually replace conventional plastics.

Moreover, the demand for eco-friendly products continues to increase, both in domestic and international markets. Several industries with particularly high demand for bioplastics include food and beverage (single-use packaging), retail (shopping bags), and agriculture (biodegradable mulch films). Consequently, if Nagan Raya is able to develop a cassava-based bioplastic industry, the region could become integrated into a promising global supply chain.

The development of cassava-based bioplastics would not only generate positive environmental impacts but also yield substantial economic and social benefits. Farmers who previously sold cassava only in raw form could gain higher added value through partnerships with SMEs or processing industries. This has the potential to enhance farmer welfare while simultaneously creating new employment opportunities at the local level.

Furthermore, the establishment of a bioplastic industry could stimulate the growth of new business ecosystems in Nagan Raya, such as processing technology providers, workforce training initiatives, and small-scale research centers to improve production quality. In this way, bioplastics could serve as a driver of the green economy while strengthening regional self-reliance in managing local natural resources.

3.4. Green Economy

The development of cassava starch-based bioplastics in Nagan Raya Regency represents a concrete step toward establishing a green economy—an economic system oriented not only toward growth but also toward environmental sustainability. By processing cassava into bioplastics, farmers gain higher added value compared to merely selling raw tubers, while society benefits from eco-friendly alternatives that can replace conventional plastics. This innovation fosters the creation of a new sustainable industrial chain, generates local employment opportunities, and reduces dependence on petroleum-based plastics that pollute the environment. Thus, cassava is no longer merely a food commodity but also a driver of green economic transformation that links community welfare with ecosystem sustainability.

4 Conclusion

Cassava, which has long been perceived merely as a staple food, in fact holds significant potential to transform the economy of Nagan Raya. The challenges of low productivity, limited technology, and traditional distribution channels have indeed placed farmers in a disadvantaged position. However, behind these limitations lies a golden opportunity. By utilizing cassava as a raw material for high-value products such as bioethanol, liquid sugar, or bioplastics, farmers can not only enhance their welfare but also contribute to the global movement to reduce environmental pollution.

Cassava-based bioplastics represent a symbol of a more sustainable future. This product not only offers a solution to the problem of plastic waste but also paves the way for the emergence of new business ecosystems in the region. With collaborative efforts among the government, academia, MSMEs, and the community, Nagan Raya has the potential to become a model of how a local commodity can evolve into a key driver of the green economy.

Thus, cassava is no longer merely a raw harvest sold in its unprocessed form, but a strategic resource capable of generating prosperity for society while preserving harmony with nature.

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