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Securing Coconut Availability in Indonesia

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ABSTRACT

Coconut shortage has been a concerning issue in Indonesia for the past few years. Using a system dynamics (SD) approach and the supply and demand ratio (S/D ratio), this study aims to build a simulation model for the sustainability of coconut supply in Indonesia. The result shows that the S/D ratio will fall below 1 by 2023, indicating that the supply will no longer meet the demands. The model suggests that the most effective policy is doubling the coconut plantations areas and increasing the yield up to 2 tons/ha of copra.

Keywords: *sustainability; coconut; system dynamics; policy.*

1 Introduction

Coconut (Cocos nucifera) roots are strong enough to withstand ocean waves and prevent coastal abrasion. It is also often used for medicinal purposes (Uy et al., 2019). The leaves can be materials for building and furniture. The husks can be turned into ropes, doormats, brooms, and planting media. The shells can be turned into kitchen utensils and high-quality charcoal. The flesh can be consumed directly or processed into food products such as coconut milk, flour, and oil. Coconut oil made from dried coconut flesh—often called copra—is refined bleached deodorized coconut oil (RBD CNO), whereas coconut oil made from fresh coconut milk is called Virgin Coconut Oil (VCO). VCO contains higher bioactive components than the RBD CNO and can be used as a healing therapy for COVID-19 patients (Angeles-Agdeppa et al., 2021). Aside from being consumed, coconut oil can be a raw material for cosmetics, soaps, and detergents. Meanwhile, coconut water is rich in minerals (Prades, 2012) and can be processed into Nata de coco (Phisalaphong et al., 2016). Finally, the sap from coconut stems can be turned into sugar.

Because of its benefits, coconut has become an essential commodity. The highest demand comes from European Union (EU) countries. The global supply is met by plantations in more than 90 countries, with the highest contribution coming from the Asia Pacific. As a critical commodity, coconut can affect a country's economy and culture. In the recent decade, coconut-derived commodities such as copra and coconut oil have faced a shortage of raw materials. Pham (2016) reported that two-thirds of the coconut plants supplying copra are too old and unproductive. Indonesia is one of the countries facing such a shortage problem to meet the existing demand (Gunawan et al., 2021). The unsustainable supply causes a negative snowball effect on many coconut-based industries. Therefore, an effective strategy to ensure the sustainability of coconut in Indonesia is needed.

Recent studies have explored the sustainability of the coconut supply chain in Indonesia, with some focusing on the socio-economics of coconut farmers in Indonesia (Ningsih et al., 2017; Rusdi, 2021; Alfaliansyah and Maswadi, 2021), while others on downstream potential and the absorption of domestic coconut products and their derivatives (Kusumawati et al., 2012; Suliyanto et al., 2013). Other research strands are interested in supply-chain risk (Citraresmi and Jusuf, 2019) and supply-chain information systems (Lumunon et al., 2018; Gunawan et al., 2018; Gunawan et al., 2019). Meanwhile, industry-specific research such as the supply chain performance of coconut (and its derivative) products (Meilizar et al., 2016) has also gained more interest recently. However, studies explicitly discussing coconut-supply sustainability remain under-researched. Alouw and Wulandari (2020) and Gunawan et al. (2021) revealed a real threat to coconut supply-chain sustainability in Indonesia. They suggested investigating the alignment of supply and demand to create a sustainable coconut supply chain. The current study offers a novel model for coconut-supply sustainability in Indonesia.

Food security cannot be achieved without ensuring food sustainability (Lang and Barling, 2012). Therefore, we study coconut availability from a food system perspective, i.e., production to consumption. The food system perspective aims to uncover the problem by looking at the relationship between elements in the supply chain. The complex system behavior can be understood through the system dynamics (SD) approach (Onggo, 2021), which identifies the system's behavior with feedback loops, and stocks and flows (Morecroft, 2010). Feedback loops are a conceptual model of a problem situation that can be translated into a dynamic simulation model with stocks and flows. This simulation can predict system parameters and suggest improvement scenarios.

The SD approach has been widely used in supply-chain sustainability research in the context of Indonesian food commodities, such as rice (Pradhito et al., 2013; Ustriyana, 2015; Wibowo et al., 2015; Avianto et al., 2017; Christian et al., 2018; Aprillya et al., 2019; Usman et al., 2019; Juned et al., 2020; Fitriyana et al., 2021a; Fitriyana et al., 2021b; Purwanto et al., 2021), soybean (Hasan et al., 2015; Oktyajati et al., 2018), cassava (Ariadi et al., 2016), salacca (Bimantio et al., 2019), brown sugar (Sumadi et al., 2020), Cananga oil (Widiaswanti et al., 2020), and salt (Muhandhis et al., 2021). Therefore, this study employs the SD approach to predict and propose strategies for coconut supply-chain sustainability. This research helps understand the current state of coconut sustainability in Indonesia and proposes a strategy to improve the supply and demand alignment in the long run.

2 Literature Review

2.1 Indonesian coconut sustainability issues

Coconut plants grow well in tropical countries, including Indonesia. It is a strategic commodity in Indonesia with significant economic, social, and environmental impacts. The production is one of the largest globally, contributing 29% of the total supply. The production meets not only the domestic needs but also the export needs to the global market (Prades, 2016). The average percentage of Indonesia's coconut export per year between 2011 and 2015 was 29.2%. The derivative products exported were crude coconut oil (CCNO), RBD CNO, and fresh coconut. North Sulawesi province shares the largest coconut export. Riau province in Sumatra also produces a significant amount of coconut, exported mainly to the neighbouring country, Malaysia.

The demand for coconut oil has been declining since the 1970s. A tentative explanation for this decline is the rise of palm oil products as a substitute for coconut oil at a much lower price. This kind of demand variation redefines the food and agriculture systems as systems that can threaten or support the sustainability of a food commodity (Campos and Madureira, 2019). The second reason is the health issues associated with coconut oil consumption, such as cardiovascular disease. Although the evidence remains inconclusive (Lima and Block, 2019), the perception discourages people from purchasing. However, recent research shows new evidence. The main content of coconut oil, lauric acid, does not lead to fat accumulation in the body. In fact, it is useful as an antimicrobial and anti-cancer (Dayrit, 2015; Deen et al., 2020). This new evidence should reposition coconut oil in the market. The derivatives of coconut products such as VCO, coconut water, and coconut sugar (Prades, 2016) are also gaining popularity. Overall, the demand for coconut will continue to grow in the coming years.

However, Indonesia's coconut processing industry has had difficulty procuring raw materials (Pramana, 2020). This shortage could affect the productivity of the coconut processing industry by up to 50%. The loss could reach USD 5.8 billion. The low supply is due to the low yields and the decrease in the coconut plantation area. The overall yield in Indonesia is between 0.8 and1.5 tons of copra/ha, with an average of 1.1 tons of copra/ha. Between 2016 and 2020, the decline in coconut plantation area was 1.93% per year (Directorate General of Estate, 2020). The production also declined considerably during the same period, 0.91% per year on average (Directorate General of Estate, 2020). Farmers and dealers prefer exporting fresh coconut to selling it to the domestic market. Association of Indonesian Coconut Processing Industries and the Association of Indonesian Food Oil Industry have submitted a formal request to the government to implement a moratorium on fresh coconut exports. This poses a dilemma because Indonesia is one of the Food and Agriculture Organization Council Members representing the Asia regional group alongside Bangladesh, the Philippines, Japan, China, and South Korea.

2.2 System Dynamics in food sustainability issue

The old food security paradigm focuses on agricultural production, but this is a misconception because production alone will not suffice. Food security needs to be considered in terms of sustainability. Lang and Barling (2012) state that a safe food system is a sustainable food system that harmonizes production, consumption, and policy. Therefore, we need a systematic approach or perspective investigating food sustainability.

The internal and external variables in a food system are interconnected through a feedback process (Brzenina et al., 2016). SD can visualize the interactions between elements and changes over time observed through feedback loops and stocks and flows. SD can also accommodate food-system interventions to achieve specific goals. Therefore, SD is one of the most effective approaches to assessing food-system sustainability (Amiri et al., 2020).

Teimoury et al. (2013) proposed a policy model for vegetables and fruit import quotas of a Tehran-based municipal organization using the SD approach. The vegetable and fruit import quota policy model considers the interaction between supply, demand, and price. Two scenarios were tested in the simulation—increased demand and decreased supply. With this, import strategies can be formulated to maintain price stability despite the supply and demand fluctuations. Christos et al. (2014) proposed a conceptual framework for food security using a causal loop diagram (CLD) that considers availability, accessibility, stability, and utilization. However, this study was not followed by a simulation to show the managerial implications. Walters et al. (2016) developed a production evaluation model in the agriculture sector using an SD approach that considers social quality, economics, environmental quality, and technology. The evaluation model examines the role of the crop production system and livestock production system independently and the role of combining the two systems. The simulation results show that the highest sustainability potential is in the crop production system.

Bastan et al. (2017) used the SD approach to study agricultural sustainability in Damavand in Tehran, Iran, from the operating system perspective. The model developed focuses on land availability and yield and formulated three improvement scenarios—increasing farmers' income, increasing irrigation, and closing illegal wells. The findings show that water resource management is a critical success factor in developing sustainable agriculture. In Indonesia, Findiastuti et al. (2018) developed a food sustainability model using the SD approach. The performance measurement indicators of the proposed scenario were the Indonesian Sustainable Food Availability (ISFA) ratio and food availability scores. These indicators simplified the explanation and made the complex model easier to understand. Meanwhile, Amiri et al. (2020) developed a food system sustainability model by focusing only on one type of commodity: wheat. The simulation results are easier to follow with only one specific commodity and area. Similar to Bastan et al. (2017), the study shows that water resource management is a critical success factor in the commodity’s sustainability. Improvements from the technological aspect also need to be prioritized as part of the sustainability strategies.

Past research has also shown that simulation models developed with the SD approach can be applied at the strategic level or operational level individually or both strategic and operational levels. The SD approach can also be used to make short-term and long-term predictions. In developing a model for food-system sustainability, focusing on a specific scope will generate better results. For example, focusing on certain commodities in certain areas can obtain findings useful at the knowledge level while providing practical implications for management. Using ratios or performance measurement indexes in model development can demystify complex models and evaluate the improvement scenarios' effectiveness.

3 Methods

3.1 Data Source

This study uses secondary data obtained from various sources. The majority of the data was retrieved from the Indonesian government's official websites, such as the Directorate General of Estate and the Central Bureau of Statistics (https://www.bps.go.id/). Additional data were obtained from the World Bank Data (https://data.worldbank.org/) and the 2009-2018 reports by the Central Data Mediatama Indonesia (CDMI) Consulting Group—an organization that issues an annual report on the Indonesian cooking oil development.

The developed model was also justified by considering the findings from research on the application of dynamic systems in the food supply chain, as well as the sustainability of certain commodities. Further, the model was checked against theories in the literature and expert opinions concerning the current coconut supply-chain situation in Indonesia.

3.2 Modelling Process

This research employs the SD approach in building the simulation model, consisting of five stages (Sterman, 2000).

Stage 1: Problem Articulation

This stage is critical to direct the whole study by identifying the problem, determining the problem time frames, the analysis level, the study limitation, and the potential factors covered.

Stage 2: The dynamic hypothesis

At this stage, a Causal Loop Diagram (CLD) is developed to explain the observed system performance. This initial illustration visualizes the system's main interactions and feedback loops, built from basic elements of words, phrases, links, and loops—with special conventions for labeling variables and describing the polarity.

Stage 3: The model's construction

The dynamic hypotheses are transformed into stock and flow diagrams with algebraic equations at this stage. Also, the feedback loops shown in CLDs are converted into stock-flow diagrams. A feedback loop is formed when a stock-flow network has direct or indirect interdependency with other stock-flow networks.

Stage 4: Testing

In this verification and validation stage, the simulation of the stock-flow network is run to verify if the behavior over time makes sense (verification phase) and is consistent with available evidence from the real-world data (validation phase). The simulation model is processed using STELLA 9.1.3 software. In the testing process, the proposed model is continuously improved until it generates results close to the real-world data.

Stage 5: The formulation and evaluation of the improvement scenarios

Once the model reproduces dynamic symptoms close to the real-world conditions, the next phase proposes improvement scenarios. The performance improvement includes proposing solutions to problems and policy changes. These scenarios are subsequently simulated to test how well they perform, assessed by improving the predefined performance parameters. Up to this point, model adjustment is still possible to accommodate the policy changes.

These five stages are presented as a cycle (Figure 1) and not as a linear sequence to indicate that the stages are interconnected. The model is shaped iteratively until close enough to the real-world conditions.

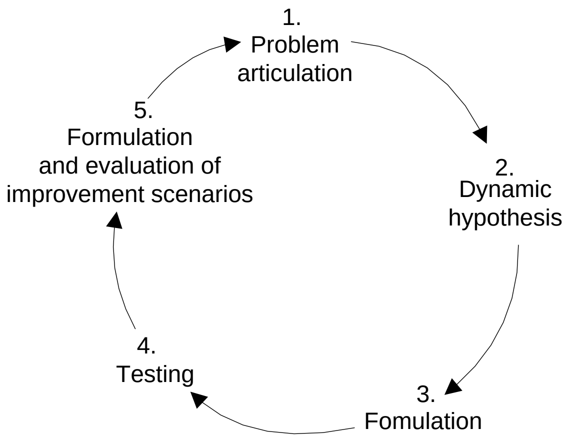

Figure 1. Iterative Modelling Process (Sterman, 2000).

4 Model Development

4.1 Problem Articulation

A native plant of Indonesia, coconut is a commodity that contributes significantly to the national economy (Bauddouin and Lebrun, 2009). Since World War II, copra has been a significant commodity for Indonesia. To date, the country remains one of the largest global coconut producers and exporters. However, the current domestic supply is facing a serious threat. Coconut-processing industries have been complaining about the shortage of raw materials in the past few years (Jaramaya, 2016; Yusuf, 2016; Iksan, 2017, Hastuti, 2019; Pramana, 2020; Indraini, 2021). This is concerning because any disruptions in coconut processing industries will also tip the balance of the coconut value chain.

The raw material shortage in the domestic market is caused by the decreasing coconut plantation areas, the aging trees, and the high exports. The fresh coconut export alone reached 25% of global demands in 2016 (Abdulsamad, 2016). The value-adding in the supply chain was not optimum because the production was low, and a large part of it was exported unprocessed. The government made a pledge to enhance the coconut downstream industries but somehow allowed the export of fresh coconut (Siregar, 2019; Aivanni, 2019). This gap between policy and practice has resulted in a serious disruption to the sustainability of the domestic coconut supply chain and inconsistent coconut supply in the domestic coconut processing industry.

4.2 Dynamic Hypothesis

The dynamic hypothesis in this study is visualized into a causal loop diagram (CLD), a descriptive-qualitative conceptual model that supports the development of a simulation model. Figure 2 shows the CLD built in this research, namely by considering the value chain in the coconut food chain. The coconut value chain starts with fresh coconuts, harvested in two stages. The first stage is harvesting coconut seven months after the flowering phase, and the second is harvesting coconut 12 months after flowering. Coconuts harvested in the first stage are referred to as ‘young coconuts’, and in the second stage, ‘old coconuts’. Young coconuts are produced for direct consumption, and old coconuts for copra manufacture, VCO, coconut milk, or coconut flour. The copra can be processed into crude coconut oil (CCO), the raw material for refined bleached deodorized coconut oil (RBD CNO) or coconut cooking oil. In other words, coconut cooking oil is the product with the most added value in the coconut food chain.

Due to the limited data availability, the conceptual model is developed with the value chain simplification, but this was made without severing the expected results. In this model, both young and old coconuts are considered fresh coconuts. From the supply side, fresh coconut production is influenced by the plantation areas, yields, and export volume. This will affect the availability of fresh coconut in the domestic market. From the demand side, domestic consumption includes direct consumption by households and raw material demand by industries to produce derivative products such as VCO, coconut milk, and coconut flour. The availability of fresh coconut, the export demand for copra, and CCO production will affect copra production. Likewise, copra production and exports will affect the domestic availability of copra to be used in CCO production. Similarly, CCO production depends on RBD CNO production and CCO export demand. Then, the production and export of CCO will affect the availability of domestic CCO. The availability of CCO, the export demand for RBD CNO, and the domestic consumption of coconut cooking oil affect the production of RBD

CNO. The availability of RBD CNO is affected by both the production of RBD CNO and exports of RBD CNO. Finally, the availability of this RBD CNO also affects the domestic consumption of coconut-derived products.

The challenge is to determine how coconut production can meet the domestic demand in the entire coconut value chain, including the highest value-adding product: the RBD CNO. The CLD in Figure 2 shows reinforcing loops that produce trend patterns, which could predict the time frame when coconut production in Indonesia can no longer meet the overall demand of the coconut food chain. It could also help determine the strategies needed to maintain supply and demand continuity in the coconut food chain. Price, production cost, and profit factors are excluded from the model development. The model also only considers a specific coconut value chain concerning food-derived products and does not consider substitute products for coconut-derived products.

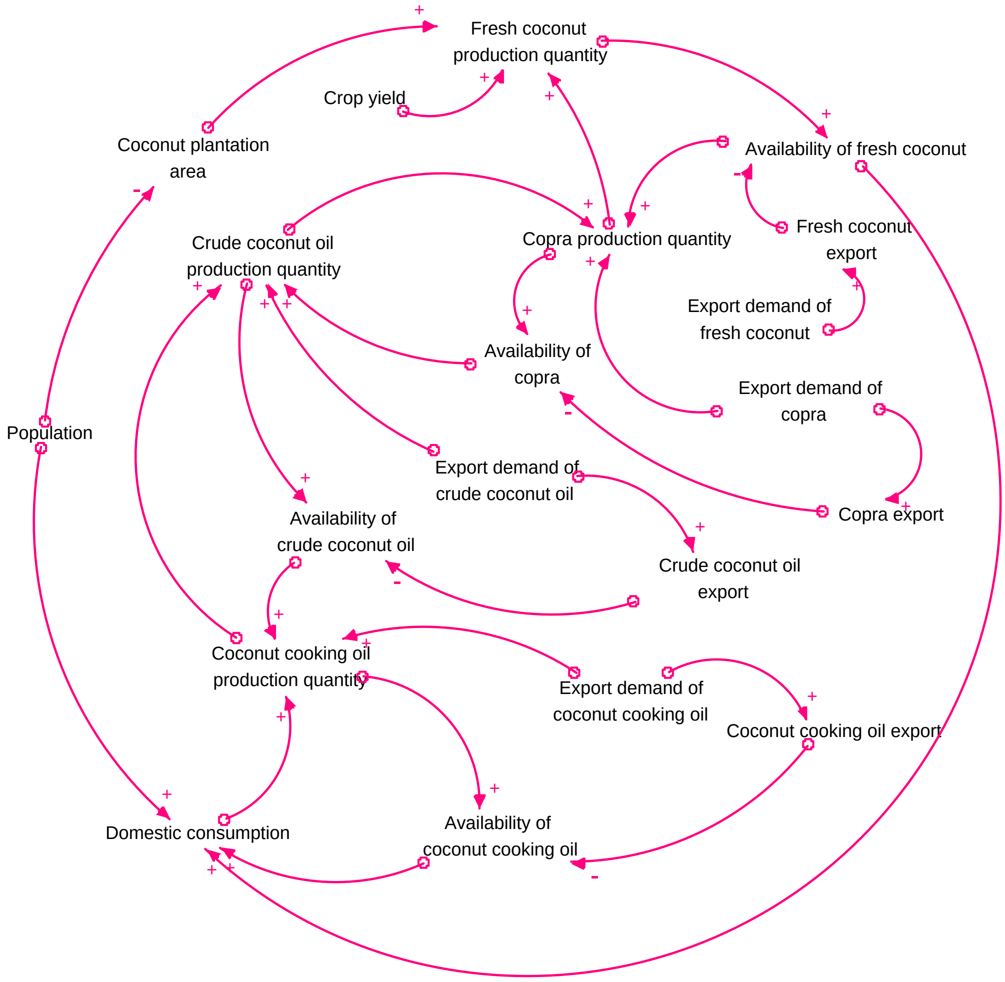

Figure 2. Causal Loop Diagram.

4.3 The Model Formulation

The conceptual model becomes the basis for formulating a computer simulation model with a stock-flow diagram (SFD) in the next stage. Figure 3 shows the SFD developed using a computer simulation program. In the SFD, the CLD elements are translated into stocks, flows, and variables. The development of SFD assumes that coconut land owned by the government is permanently fixed. The supply and demand ratio (S/D ratio) is used as model parameters to see the effectiveness of the proposed improvement scenarios. The S/D ratio > 2 indicates that the supply can meet demand. The S/D ratio between 1 to 2 shows that the supply will still manage to meet demand. The S/D ratio is < shows the inability to meet demand. The equations for calculating supply, demand, and S/D ratio are shown in Equations 1, 2, and 3.

$$Supply = Yield * Total\ plantation\ area \quad (1)$$

$$Demand = Total\ consumption\ of\ fresh\ coconut + Total\ consumption\ of\ copra \quad (2)$$

$$\frac{S}{D} ratio = Supply/Demand \quad (3)$$

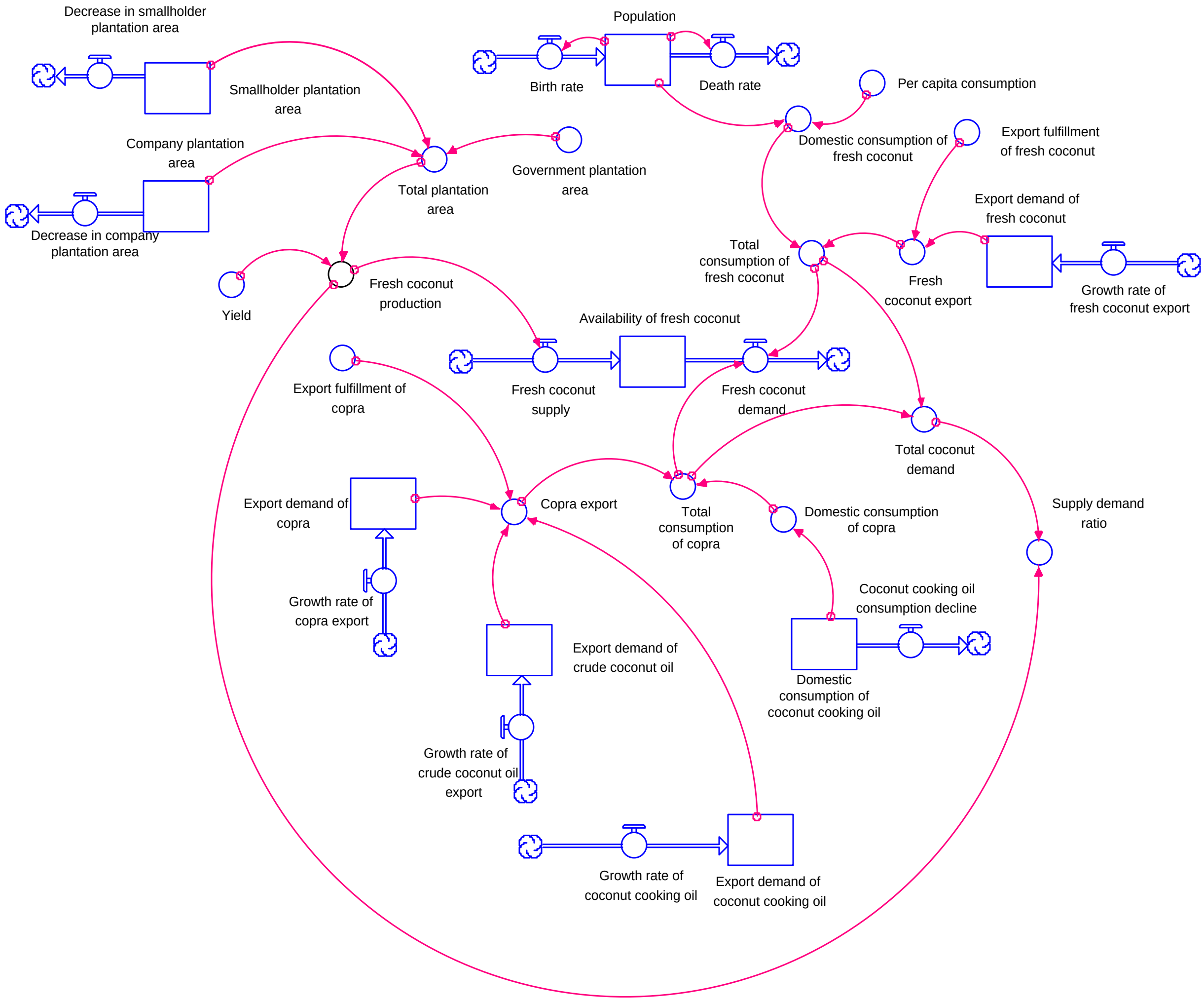

Figure 3. Stock Flow Diagram.

4.4 Testing: Verification and Validation

The verification aims to ensure that the model is reliable because it is necessary to check the consistency between the conceptual model and the simulation model (Sargent, 2013). The functions in the simulation model are verified by checking the unit consistency of each variable. The verification was performed using STELLA software to detect inconsistency in the unit. Further, the model structure is checked by looking at the behavior of the reinforcing loop and whether it produces the pattern properly.

The validation was carried out to ensure whether the model could represent the real system. One method used to prove this is by performing statistical tests between simulated and historical data (Sargent, 2013). The two-sample t-test was used to see if there was a difference between the historical data and simulation data (results). The historical and simulation data used in the test can be seen in Table 1.

Table 1.
Historical Data vs Simulation Data.

Year	Coconut Production Historical Data (kg)	Coconut Production Simulation Data (kg)
2009	3,257,969,000	3,380,343,905
2010	3,166,666,000	3,304,284,981
2011	3,174,378,000	3,234,432,658
2012	3,189,897,000	3,266,278,875
2013	3,051,585,000	3,056,049,169
2014	3,005,916,000	2,969,901,232
2015	2,920,665,000	3,002,309,653
2016	2,904,170,000	2,891,819,747
2017	2,854,300,000	2,879,560,561
2018	2,840,148,000	2,854,109,689

The two-sample t-test was conducted using the Minitab software. The result shows a p-value of 0.555, which is greater than 0.05, so H_0 is accepted. There is no significant difference between historical and simulation data, and the model can be declared valid. In addition to the statistical test, the mean absolute percentage error (MAPE) from 2009 to 2018 was also calculated. The MAPE value is small at 1.833%, indicating that the simulated data match the historical data.

4.5 The Formulation and Evaluation of the Improvement Scenarios

4.5.1 The Base Scenario

The base scenario shows the model prediction of coconut availability in Indonesia based on the existing condition (without any intervention) from 2009 to 2090. Figure 4 and Table 2 present the S/D ratio in the base scenario.

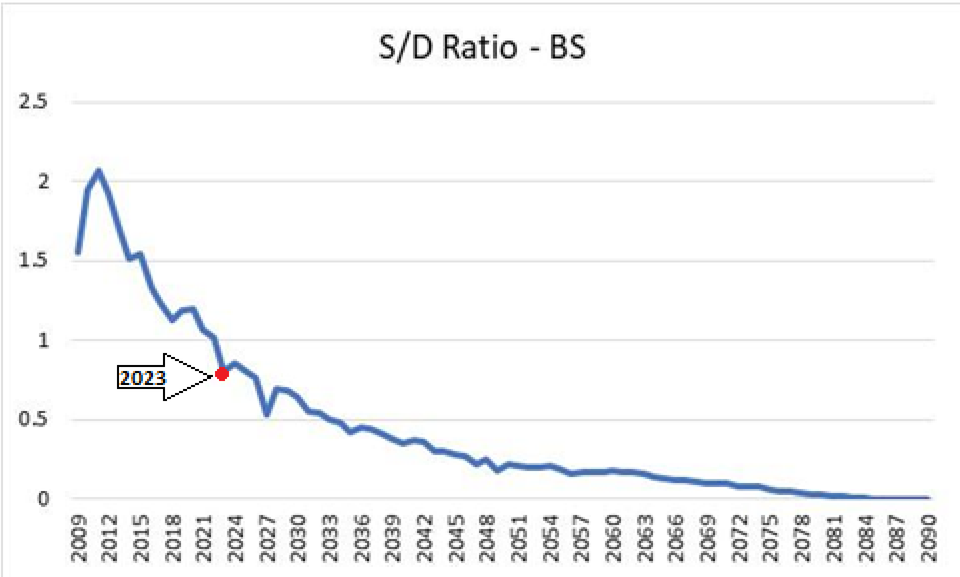

Figure 4. The Time Series Plot of the S/D ratio.

Table 2.
S/D Ratio of base scenario every ten years.

Year	S/D ratio
2011	2.07
2021	1.07
2031	0.55
2041	0.37
2051	0.21
2061	0.17
2071	0.1
2081	0.02

Figure 4 shows that the S/D ratio sees a constant downward trend. In 2023, Indonesia's coconut supply is predicted to fail to meet the demand, with the S/D ratio being 0.8. Table 2 demonstrates that the S/D ratio for every ten years will continue to decline to 0.2 in 2081. This finding supports the premise that Indonesia is experiencing a shortage of coconut supply. If the production of fresh coconut is not optimized, there will be a further shortage of coconut raw materials for coconut-derived products.

4.5.2. The Improvement Scenarios

This study proposes nine improvement scenarios to solve the coconut supply chain problems: four single and five combination scenarios. The proposed single scenarios are maintaining coconut plantation areas (S1), increasing average yield to 2 tons/ha (S2), increasing land areas to 7 million ha (S3), and limiting fresh coconut and copra export quotas to a maximum of 60% of the demand (S4). Meanwhile, the proposed combination scenarios consist of two or three single scenarios. The first combination is maintaining land areas and increasing the average yield to 2 tons/ha (S5). The second combination is increasing land areas to 7 million ha and increasing the average yield up to 2 tons/ha (S6). The third combination is maintaining coconut plantation areas and limiting export quotas (S7). The fourth combination is increasing the average yield to 2 tons/ha and limiting export quotas (S8). The fifth combination is maintaining coconut plantation areas, increasing the average yield to 2 tons/ha, and limiting export quotas (S9).

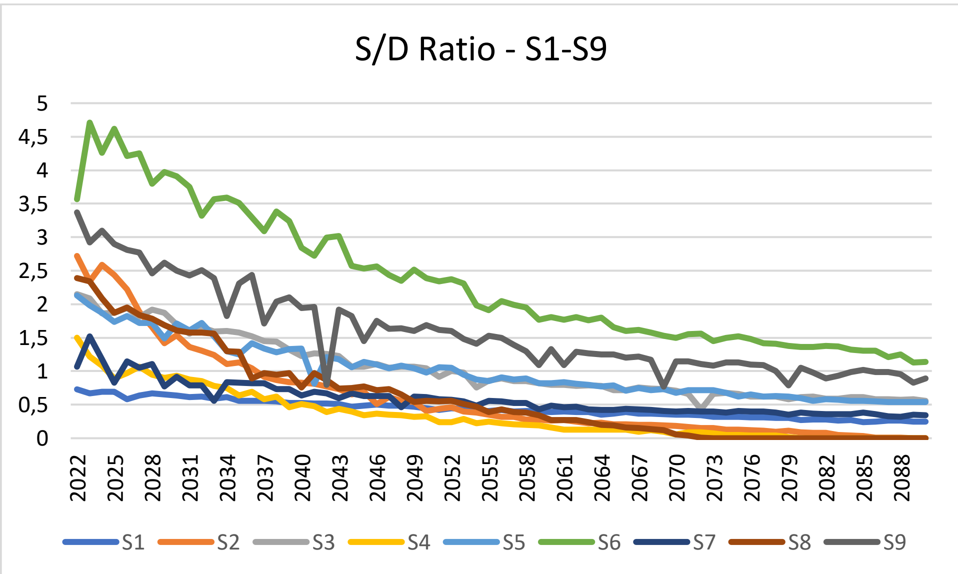

Figure 5. Time Series Plot of S/D Ratio for Improvement Scenarios.

Table 3.
The Projected 10-year S/D Ratio for each Improvement Scenario.

Year	Improvement Scenario								
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
2031	0.61	1.36	1.56	0.88	1.61	3.75	0.79	1.58	2.43
2041	0.52	0.81	1.27	0.48	0.81	2.72	0.69	0.97	1.96
2051	0.42	0.44	0.92	0.24	1.06	2.34	0.58	0.55	1.62
2061	0.4	0.27	0.8	0.13	0.84	1.77	0.46	0.27	1.09
2071	0.35	0.17	0.66	0.09	0.72	1.55	0.41	0.04	1.15
2081	0.28	0.08	0.62	0	0.56	1.36	0.37	0	0.98

Figure 5 and Table 3 show that the best scenario for increasing coconut availability is increasing the land area to 7 million ha and the average yield to 2 tons per ha (S6). The simulation result for S6 shows that the policy models could maintain the S/D Ratio >1 until 2090. The second-best scenario is the combination of maintaining coconut plantation areas, increasing average yield to 2 tons per ha, and limiting export quotas for fresh coconut and copra to a maximum of 60% of demand (S9). Scenario 9 considers a possibility where coconut plantation areas cannot be expanded. Therefore, the quality of the existing plantation area should be maintained and improved instead. Increasing yield to 2 tons/ha is a necessary step to maintain a sustainable coconut supply. This scenario also suggests that the government should reduce exports. Overall, it guarantees the S/D ratio will be maintained at 0.9 in 2090.

However, one limitation of the proposed improvement scenarios is that these cannot be implemented in a short period (one year) as assumed in the model simulation. It takes longer than a year to expand plantation areas and increase land productivity. Therefore, the S/D ratio results from the improvement scenarios may not be accurate. Nevertheless, this does not affect the final results expected in this study, that is, to establish the best scenario to maintain the sustainability of the coconut industry in Indonesia.

5 Discussion

The SD model for predicting coconut availability trends in Indonesia is more suitable than the time series model because the SD method focuses on how a system works (Reynolds and Holwell, 2010). This approach studies the interactions between elements in the system so that it is possible to see the effectiveness of an intervention strategy (Gary et al., 2008). With the SD approach, future studies can focus on potential strategies to ensure the sustainability of coconut supply in Indonesia and determine which one is the most promising.

The simulation results with SFD show that increasing plantation areas to 7 ha—which is two times wider than the current area—and increasing yield up to 2 tons/ha (S6) is the most effective strategy. Doubling plantation areas is feasible because Indonesia has the longest coastline globally, and coconut trees grow well along the coastline. The eastern part of Indonesia, which is currently low in population density (under 2,000 inhabitants per km^2), can also be developed into coconut plantation centers. These provinces can accommodate the ideal distance requirement for coconut cultivation, which is approximately 9 meters. This land expansion could also be supported by agricultural diversification, i.e., an intercropping system that allows the in-between land to remain productive.

Increasing yield to 2 tons/ha is also feasible with the support of agricultural technology, especially the development of superior and hybrid coconut seeds. Currently, the coconut plantation in the Special Region of Yogyakarta, Indonesia, can achieve 1.5 tons per ha (Directorate General of Estate, 2020). A program to increase yield through the rejuvenation of coconut plants is needed, considering the current non-productive coconut plants are nearly 10% of all plantation areas in Indonesia. In addition, with the yield in the range of 1.1 tons/ha equivalent to copra, the gross income earned by farmers is only around USD500-700/ha/year. This income is low, which impacts farmers' productivity and leads to structural poverty among farmers in the long run (Anang et al., 2020). Although the results of S6 sound promising, these two strategies require appropriate long-term policies, orchestration by the government, and periodic policy monitoring and evaluation. For example, transparency and information sharing between parties in the agricultural supply chain can facilitate farmers in adopting new varieties to increase yields (Zmazhenko et al., 2020).

The second-best scenario is the combination of maintaining the current plantation areas, increasing the average yield to 2 tons/ha, and limiting export quotas (S9). This scenario will be an option if land expansion is not feasible. Maintaining plantation areas can be done by providing incentives to landowners to encourage them to maintain their farms and minimize the intention to sell the land or use it for other purposes. In addition, the government needs to restrict the export of fresh coconut and copra so that domestic production can meet domestic demands. By considering the current coconut availability, the recommended scheme is at a maximum of 60% of the export demand. The government could restrict the export of raw materials by setting tariff barriers in the form of a progressive export tax on exports of raw materials. Through these various proposed strategies, it is possible that Indonesia can maintain the coconut supply chain and ensure the sustainability of both the domestic and global coconut food chains over a long period.

6 Conclusion

The SD approach successfully predicts coconut supply and demand in Indonesia. The simulation results show that in 2021, the supply of coconut in Indonesia could not meet domestic and export demand growth. As one of the largest coconut producers globally, Indonesia needs a scenario to maintain the coconut supply chain by expanding the land area and increasing the average yield. If land expansion is not feasible, the second-best scenario is to maintain the existing land areas while increasing the average yield of up to 2 tons per ha equivalent to copra and setting export quotas for fresh coconut and copra to a maximum of 60% of the demand. To improve the domestic coconut value chain, the government needs to implement tariff barriers for fresh coconut and copra exports.

One of the obstacles in conducting this research is the data limitation and discrepancies among various sources. The selection of reliable sources significantly limits the fulfilment of the required data. Another limitation is the researcher's subjectivity in modelling development and improvement scenario formulation. Although this has been overcome by literature review and experts' judgment, the subjectivity may still hold. In addition, the predicted numbers using the SD approach tend to be less accurate than other mathematical approaches because it focuses more on understanding the structure and behavior of a system. However, the SD approach has the flexibility in developing predictive models and behavioral intervention models. The suggestion for further research is to look at the role of commodity prices in coconut supply-demand sustainability in Indonesia and the effect of substitute products such as palm oil.

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