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Policy Scenarios in Optimizing Banggai Yam Production to Meet Future Demand

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ABSTRACT

The current understanding of food security significantly impacts agricultural policy, especially regarding the availability of food to meet local and national needs. The Banggai yam is a local carbohydrate crop in Banggai Islands Regency that plays a vital role in food diversification and security. Thanks to its high carbohydrate content, this tuber has great potential as a food reserve and an alternative to rice to support food sovereignty in Banggai Islands Regency. To cope with the increasing demand, a comprehensive development plan is needed. This research aims to develop a model of Banggai yam production and needs as a fulfilment of food availability in the Banggai Islands Regency. This research uses a dynamic system approach. The dynamic system can describe the relationship between various variables in its development. The results of the study indicate that the current level of Banggai yam production is insufficient to meet overall demand. Currently, there is a production deficit of 1,703.54 tons for Banggai yam in 2018, which is projected to decrease to 1,514.9 tons by 2042. Simulation results indicate that with a 1.2 percent increase in the planting index, a 1 percent expansion of new land, and a 4 percent increase in exports in Scenario 1, which is overall moderate, a surplus of 3.3 tons will be achieved, with production reaching 11,846.8 tons and demand at 11,843.5 tons. This scenario will meet the total demand for Banggai yam until 2042. Successful implementation depends on the involvement of various stakeholders, including the government, farmers, and businesses involved in Banggai sweet potato production, making this commodity a flagship food product in Banggai Islands Regency.

Keywords: Banggai yam export; Dynamical system; New lands; Planting index

INTRODUCTION

The agricultural sector has become a priority for countries worldwide, including Indonesia. A key aspect of regional development in agriculture is the necessity for regions to achieve food self-sufficiency. According to Saranya, Deisy, Sridevi, and Anbananthen (2023), the agricultural sector is one of the main sources that plays a major role in the world's food suppliers. Furthermore, Pragatheeswari et al. (2024), stated in their study that agriculture plays an important role as a leading producer with a focus on cultivation and food safety. Therefore, it needs intensive handling as a form of sustainable agriculture that is safe and of high quality (Lalpekhlua, Tirkey, Saranya, & Babu 2024). In addition, the agricultural sector plays a key role in strengthening national economies by creating employment opportunities, increasing income, and reduce poverty (Yar & Noori 2024). Agricultural resources and traditional communities act as markets for products produced by the agricultural sector. These elements are critical to the global food system, providing raw materials that support producers through traditional agricultural practices (Sohail, Mustafa, Ali, & Riaz 2022).

The perspective on food security significantly influences agricultural policy, particularly regarding food availability. According to Savary et al. (2022) while the relationship between these two areas is often misaligned, certain aspects should be jointly addressed to develop effective strategies for enhancing food security at both national and international levels. Behera, Haldar, and Sethi (2024) suggest reframing food security as a policy dimension focused on agricultural availability, emphasizing independent food production activities involving government and community efforts. As highlighted by Beyranevand and Leib (2017) and the FAO, IFAD, UNICEF, WFP and WHO (2022), effective governance strategies include implementing policy mechanisms that facilitate national trade in food and agricultural products. Such mechanisms are essential to ensuring adequate access to sufficient food supplies, thereby supporting sustainable food security (Zhang & Han, 2025).

Food plays a strategic role in a country's social, economic, and political landscape (Hosseini, Qhalibaf, Moussavi Neghabi, & Hosseini, 2024; Kemmerling, Schetter, & Wirkus, 2022). Consequently, local governments should prioritize local food utilization programs, such as Banggai yam, as a viable strategy to enhance food availability and support national food security (Fauziah, Mas'udah, Hapsari, & Nurfadilah, 2020). This commodity is crucial within the food sub-sector, significantly contributing to the food security of both local and national populations. There is a growing demand for processed products derived from this commodity, including chips, dodol, pudding, flour, and analogue rice (Sattu et al., 2024).

The demand for this commodity has been rising annually, yet it remains unmet due to limited production. Data from the Agriculture Office of Banggai Islands Regency (2022) indicate a significant decline in Banggai yam production, primarily because planting occurs only once a year, despite the potential for biannual cultivation. The region still possesses ample suitable land for agriculture. Thus, an effective policy strategy would be to optimize land management by increasing the cropping index and utilizing available land resources. Research by Rusmawan, Muzammil, Ahmadi, and Wibawa (2021) and Sollen-Norrlin, Ghaley, and Rintoul (2020) supports that enhancing the planting index could effectively boost production, thereby addressing the demand for increased and sustainable output.

To achieve this, researchers aim to understand the effects of various system variables through dynamic system simulation. This method is effective in addressing issues within the system arise from the interdependencies of different variables (Forrester, 1997; Sumargo et al., 2024; Widiatmaka et al., 2014). The systems approach encompasses multiple elements, including land planning and management, which can impact production and inform policy recommendations aligned with specific objectives. Dynamic systems employ computer-based techniques for policy analysis and design (Eriyatno, 2012; Gerami Seresht & Fayek, 2020; Randers, 1997). Additionally, they provide a framework for managing complex and evolving systems (Dudin, Wiranatha, & Sadyasmara 2019). Dynamic problems are characterized by quantities that fluctuate over time, with these variations explained through cause-and-effect relationships (Eidin et al., 2024; Firmansyah et al., 2023).

Key factors influencing the development of Banggai yam include the production system, particularly land availability and planting index. To meet the rising demand needs for Banggai yam, a comprehensive development plan is essential. The objective of this research to model the development of Banggai yam using a system dynamic approach.

RESEARCH METHOD

Location and Time of the Study

This research was conducted in Banggai Islands Regency from July 2023 to January 2024, as this region is recognized as the center of Banggai yam production. Study Location area is spread across 12 districts, as shown in Figure 1. The study utilized a system dynamics methodology, aiming to develop a model that illustrates the mutual influence among various variables.

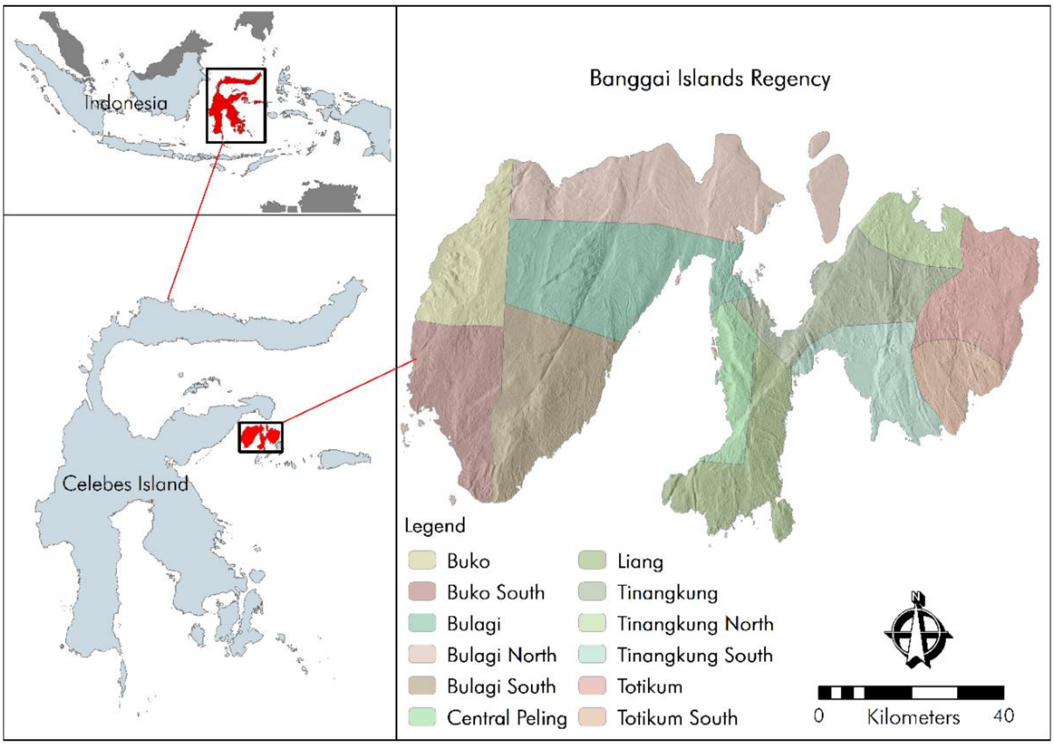


FIGURE 1. STUDY LOCATION

Data Collection

Respondents were purposively selected from subdistricts recognized as centers of Banggai yam production in the study area. This study utilized both primary and secondary data, encompassing quantitative and qualitative information. Primary data were collected through field surveys, which included interviews with respondents and experts, as well as the use of questionnaires. Secondary data, such as production figures, planting area, and consumption statistics, were obtained from the Food Security Agency and the Agriculture Agency of Banggai Kepulauan Regency, as well as supporting literature studies. Data analysis involved descriptive methods for quantitative and qualitative information. Stratified random sampling was used to ensure representation from each stratum, resulting in a sample that accurately reflected the population while minimizing variability and improving the accuracy of estimates. The interviews involved 65 farmers, 3 entrepreneurs, 2 representatives of non-governmental organizations, 4 local government officials, and 2 academics or researchers. The farmers participating in this study were married, elderly, and had more than 15 years of farming experience, thus possessing extensive knowledge about Banggai yam cultivation. The entrepreneurs are involved in Banggai yam production for food products, such as chips and others. Government respondents included extension officers from the Agriculture and Food Security Department, who play a crucial role in disseminating agricultural information to farmers. The academics selected were lecturers with expertise relevant to this study.

Data Analysis

Dynamic system analysis aims to comprehend the generation of dynamic systems and to formulate managerial policies for improvement (Dace, Bazbauers, Berzina, & Davidsen 2014). The subsequent step involves identifying the system by creating input and output diagrams (Eriyatno, 2012). To clarify the relationships between variables, both inputs and outputs are represented using causal relationships in a Causal Loop Diagram (Dhanshyam & Srivastava, 2021; Suryani, Rafi, & Utamima, 2024). This causal loop also defines the boundaries of the system under study. Additionally, Firmansyah et al. (2023) noted that for simulations, data grouping and input data are integrated into the model structure via a Stock Flow Diagram, facilitating the formation of system behavior. Dynamic system modeling is essential for evaluating changes and their impacts (Morcillo, Franco, & Angulo, 2018; Nelles, 2020; Sardo & Jalalkamali, 2022). As stated by Sumargo et al. (2024) , dynamic systems represent a valuable analytical method for both short- and long-term evaluations. The development process of a dynamic model for Banggai yam involves analyzing needs, formulating problems, identifying the system, modeling, simulating, and validating the model.

System Needs and Problem Formulation

The system needs assessment involves inventorying stakeholders, including government officials, farmers, business representatives, non-governmental organizations, and researchers, to outline their requirements. A needs analysis is then conducted using a checklist to qualitatively and quantitatively evaluate the importance of each stakeholder's needs. This process aims to clarify the significance of the anticipated system behavior. The factors and their importance levels were derived from brainstorming sessions and expert judgments, which were subsequently validated with stakeholders at the research site (Apriadi, Setiawan, & Firmansyah, 2024).

A prevalent issue in the development of Banggai yam as a local food source is the imbalance between the availability and demand for rice in the region. These systemic problems hinder the effectiveness of the development process. Conflicts of interest among stakeholders present challenges that must be addressed to ensure the system operates constructively toward its goals. Solutions involve identifying the specific issues faced by each stakeholder and understanding the influence of others. The problem formulation arises from the variables in the needs analysis that hold the highest values, which are then developed into the relevant issues within the studied system (Veríssimo, Pereira, Fernandes, & Martinho, 2024).

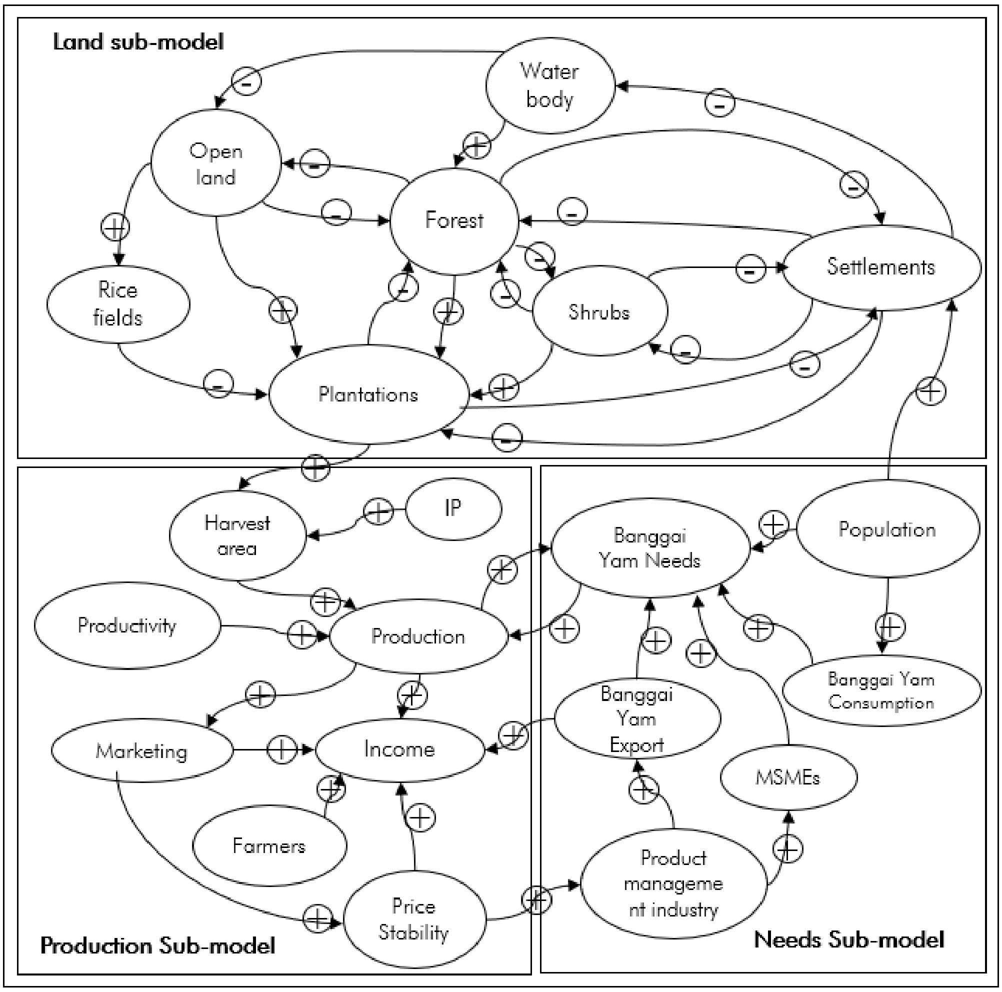


FIGURE 2. CAUSAL LOOP DIAGRAM

System Identification

System identification aims to provide a comprehensive overview of the studied system through a diagram that illustrates the relationship between input components and the environmental system, resulting in both controlled and unintended outputs. As noted by Pan et al. (2020), this stage involves identifying fundamental initial problems to generate alternative solutions based on the specific issues being examined. The relationships among these variables are expressed as mathematical equations that reflect their interdependencies (Firmansyah et al. 2023). For the development of Banggai yam, the causal loop is constructed using correlation data related to changes in land use, production, and demand to analyze their interrelations. This approach allows for the simplification of future condition changes through a causal loop relationship (Figure 2). Subsequently, an analysis is conducted to draw conclusions that inform strategies for anticipating or modifying system behavior based on the output scenarios.

Model Simulation

The simulation results from the dynamic system modeling were utilized to analyze the behavioral trends of the model. The outcomes of the simulation were examined, identifying the factors influencing these trends and elucidating the mechanisms based on the model's structural analysis. This study considers Banggai yam cultivation in the Banggai Islands Regency of Central Sulawesi Province as a modelable system. The developed model comprises three sub-models: 1) land, 2) production, and 3) Needs. The research was conducted using *Powersim Studio 10 software*.

Model Validation

During the model validation phase, the accuracy is assessed by comparing the magnitude and nature of the errors. This involves two key metrics: 1) Absolute Mean Error (AME), which measures the deviation between the average simulation results and the actual values, and 2) Absolute Variation Error (AVE), which assesses the difference between the simulated variance and the actual variance. An acceptable deviation threshold is set at less than 10 percent (Firmansyah et al., 2023; Widiatmaka et al., 2014).

$$AME = [(Si - Ai)/Ai] \quad (1)$$

$$AVE = [(Ss - Sa)/Sa] \quad (2)$$

Description: $Si = Si\ N$, where S denotes simulated value; $Ai = Ai\ N$, where A denotes actual value; N denotes observation time interval; $Ss = ((Si - Si)^2\ N)$ = deviation of simulated value; $Sa = ((Ai - Ai)^2\ N)$ = deviation of actual value.

RESULTS AND DISCUSSION

Banggai Yam Development Sub-Model in Banggai Islands Regency

Identified key variables influencing production increases as income and the role of farmers, while Suryani, Chou, Hartono, amd Chen (2010) and Al-Aziz and Suryani (2024) emphasized the importance of planting area, costs, and planting index. The production sub-model of this study incorporates variables such as land area, planting index, harvest area, productivity, price, income, and the involvement of farmers in cultivating Banggai yam. Notably, the harvested land area and planting index are critical factors for enhancing production in the Banggai Islands Regency. The model indicates that increases in new land and planting index positively affect annual Banggai yam production. It assumes a 1 percent annual increase in existing land area, with the average planting index for Banggai Yam reported as 1.00 by the Food Security Office. Typically, Banggai yam farmers engage in one planting cycle per year. The primary aim of the production sub-model is to evaluate the yield of Banggai yam as a food source in the Banggai Island Regency, thereby determining the land area necessary to meet the region's overall demand for this crop.

The demand sub-model is based on three primary assumptions: local food demand for MSMEs, population consumption variables, and export demand for Banggai yam in the food industry. Local food consumption is significantly affected by population size and per capita consumption (Bandara, Kumara, Dharmadasa, & Samaraweera, 2021; Lian, Gu, Yang, Wang, & Li, 2023), which this study estimates at 45 kg per person annually in Banggai Kepulauan Regency. The research assumes a population growth rate of 0.96 percent, with a total population of 117,526 in 2018. Additionally, the study indicates that industrial demand for Banggai yam totals 120 tons from three MSMEs, alongside an export demand of 2,500 tons in 2018.

The land use sub-model examines the relationships among various land uses, including forests, plantations, settlements, rice fields, shrubs, open land, and water bodies. It was developed using a matrix derived from land use change analysis between 2002 and 2022, interpolating data to establish a baseline for 2018. In the Banggai Islands Regency, land use data for Banggai yam focuses on plantation areas, as local farmers typically engage in shifting agriculture with mixed cropping patterns, employing an agroforestry system. According to Mwase et al. (2015), agroforestry systems provide significant benefits as conservation technologies, influenced by cultural compatibility with local communities, and offer economic advantages for farmers in both the short and long term (Plieninger, Muñoz-Rojas, Buck, & Scherr, 2020; Wu & Liu, 2024).

Furthermore, the land use sub-model is interconnected with the production and crop needs sub-models, as land serves as the foundation for cultivation activities (Mardhiana, Suryani, Asfari, & Nasrullah, 2021). An increase in harvested land for Banggai yam directly boosts production, while also balancing the community's need for residential land. Suliman, Setiawan, and Syartinilia (2022) explain that these sub-model variables are represented in a Stock Flow Diagram (SFD), designed to project future conditions of production, land use, and crop needs. The SFD constructed from these variables is illustrated in Figure 3.

Simulation of Banggai Yam development model in Banggai Islands Regency, Central Sulawesi

Simulation models in dynamic systems are designed to analyze and predict system changes, aiding in policy formulation and decision-making for sustainable food systems (Leeuwis, Boogaard, & Atta-Krah, 2021; Sušnik, Masia, Indriksone, Brēmere, &

Vamvakeridou-Lydroudia, 2021; Sy et al., 2021). The production sub-model simulation reveals that in 2018, Banggai yam demand reached 7,908.67 tons, while production was 6,205.13 tons, resulting in a deficit of 1,703.54 tons.

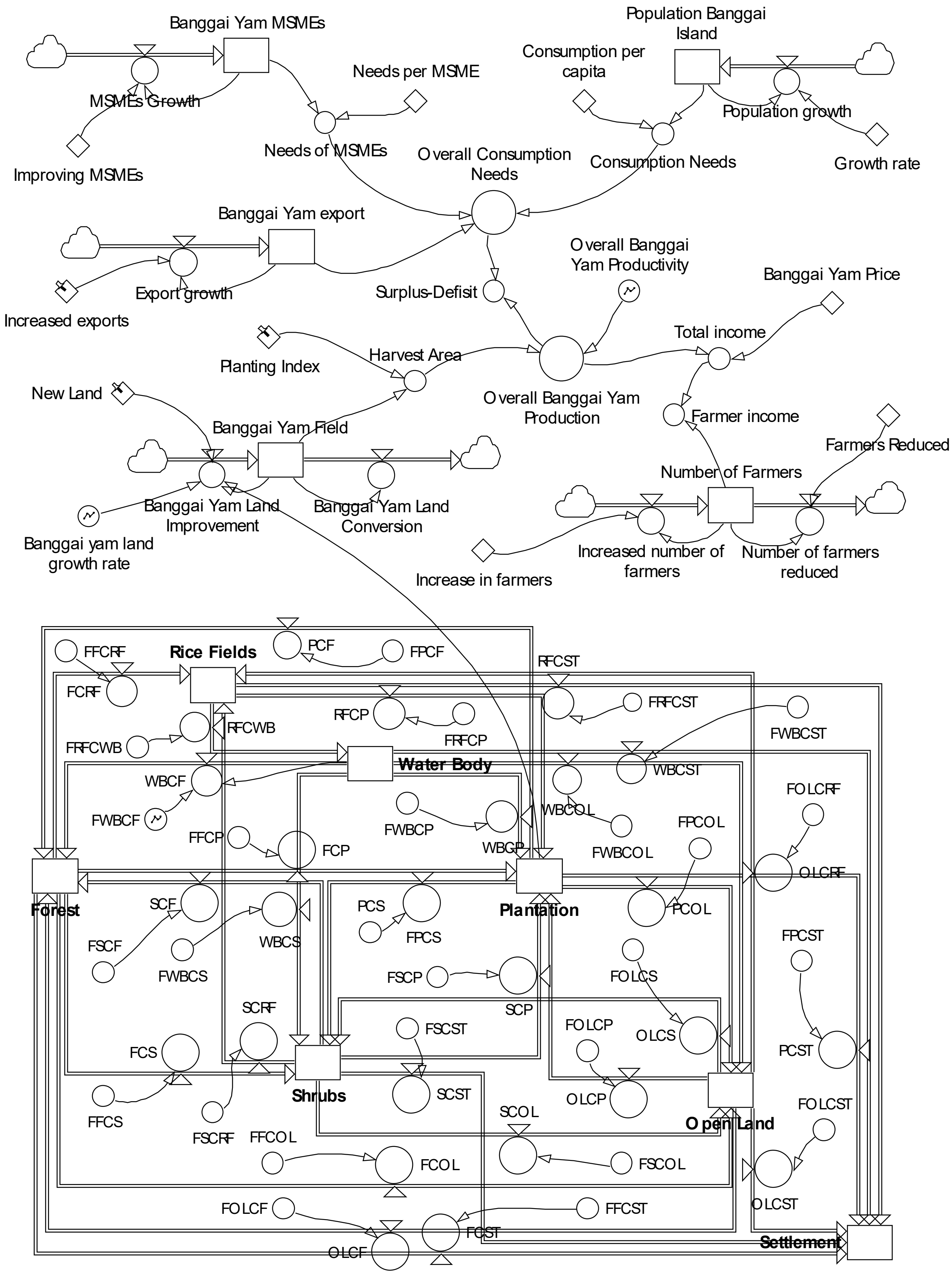
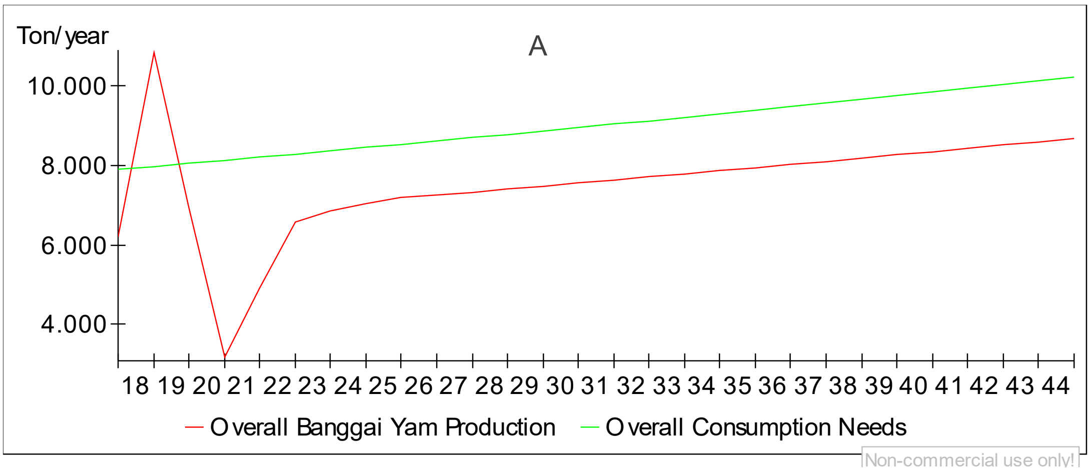


FIGURE 3. STOCK FLOW DIAGRAM OF PRODUCTION, NEEDS AND LAND USE SUB-MODELS

Projections for 2042 indicate a continued shortfall of 1,514.9 tons, with production estimated at 8,432.6 tons and demand at 9,947.5 tons. To address this gap, increasing the harvest area and improving the planting index are essential. Currently, farmers in the Banggai Islands Regency plant Banggai yam only once a year, despite the availability of extensive suitable land. Simulation results for both production and demand sub-models highlight the need for these measures, as demand for Banggai yam is projected to rise annually. Expanding harvested land and optimizing planting cycles are critical strategies to meet future demand and ensure sustainable production.



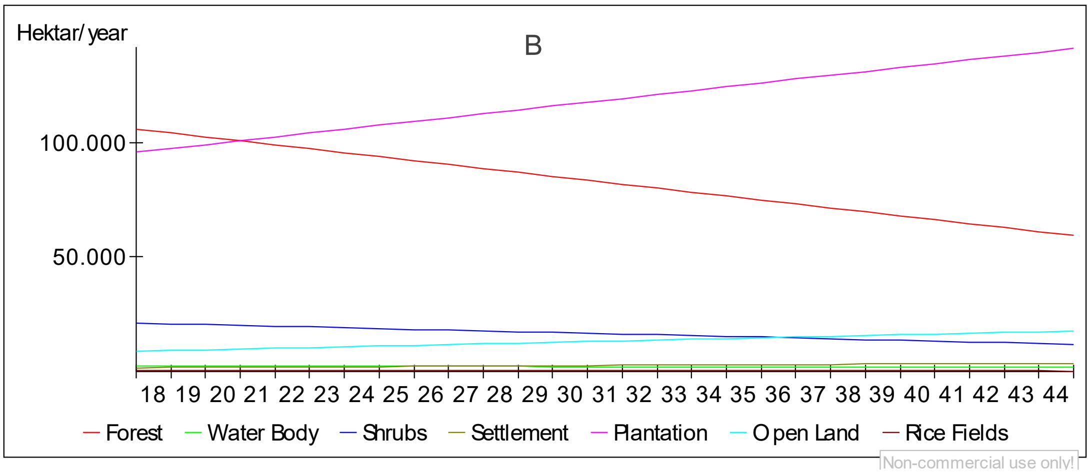


FIGURE 4. SIMULATION OF BANGGAI YAM DEVELOPMENT BASE ON PRODUCTION AND NEEDS SUB-MODEL (A), AND LAND USE SUB-MODEL (B)

The simulation of forest land use indicates a consistent decline in forest area, decreasing from 106,075.2 hectares in 2018 to 64,706.9 hectares by 2042, with an average annual loss of 1,723.7 hectare per year. Similar reductions are observed in shrubs, rice fields, and water bodies, which decreased from 21,137.5 hectares, 326.7 hectares, and 2,418.9 hectares in 2018 to 12,934 hectares, 209.1 hectares, and 1,878.4 hectares, respectively. Conversely, plantation land use hectares expanded significantly, increasing from 95,858 hectares in 2018 to 136,310 hectares in 2042, including areas used for Banggai yam cultivation, which grew from 298.8 hectares to 395.7 hectares during the same period. This expansion, averaging 1,667 hectare/year, is attributed to underutilized land resources (Liu et al., 2020). Other land uses, such as settlements and open land, also increased. Settlement areas grew from 1,629.7 hectares in 2018 to 3,412.9 hectares in 2042, driven by population growth and urbanization (Litasari, Widiatmaka, Munibah, & Machfud, 2022; Mansour, Alahmadi, Atkinson, & Dewan, 2022). Open land expanded from 8,783.2 hectares to 16,777.6 hectares, with an annual increase of 333.1 hectare/year. The projected simulation model provides insights into future conditions for production, land use, and demand by 2042, as illustrated in Figure 4.

Validation of the Banggai Yam development model in Banggai Islands Regency, Central Sulawesi

According to Firmansyah, Widiatmaka, Pramudya, and Budiharsono, (2019) and Firmansyah, Pramudya, and Sadikin (2020), model validation is conducted by comparing simulation results with actual data on Banggai yam production, needs, and land in the research area. Data from the Food Crops Service indicates that the demand for Banggai yam as a food source has been steadily increasing. However, in recent years, production has consistently fallen short of meeting consumer demand, including population consumption, MSMEs, and export needs. Results of the model validation have been presented in Table 1.

TABLE 1. VALIDATION OF PERFORMANCE IN PRODUCTION, NEEDS AND LAND USE SUB-MODELS

Validation Data		Year		Mean	AME	AVE
		2018	2022			
Production	Actual	6,205.13	4,896.15	6,411.18	0.017	0.033
	Simulation	6,206.17	4,896.97	6,412.25		
Needs	Actual	7,620	8,202.8	8,003.14	0.733	1.470
	Simulation	7,908.7	8,216.4	8,061.81		
Forest	GIS	106,075.2	97,142.8	102,144.9	0.473	0.920
	Simulation	106,075.2	99,181.1	102,628.2		
Plantation	GIS	95,858	104,193	99,525.4	0.321	0.670
	Simulation	95,858	102,553	99,205.6		
Settlement	GIS	1,629.7	1,969.7	1,786.5	0.534	1.395
	Simulation	1,629.7	1,924.2	1,777		
Open Land	GIS	8,783.2	10,407.5	9,497.9	0.511	1.153
	Simulation	8,783.2	10,115.6	9,449.4		
Rice Field	GIS	326.7	314.5	311.7	0.284	3.904
	Simulation	326.7	307.1	313.4		
Shrubs	GIS	21,137.5	19,430.9	20,386.6	0.330	0.642
	Simulation	21,137.5	19,770.3	20,453.9		
Water Body	GIS	2,418.9	2,666.8	2,408	0.610	1.890
	Simulation	2,418.9	2,328.1	2,373.5		

The validation of the production, needs and land use sub-models is presented in Table 1. The Banggai yam production sub-model achieved an Average Mean Error (AME) of 0.02 percent and an Absolute Variation Error (AVE) of 0.033 percent, indicating a strong validation level. Similarly, the needs sub-model demonstrated an AME of 0.73 percent and an AVE of 1.47 percent. Furthermore, the results of the validation of this use sub-model show that the Average Mean Error (AME) validation value for forest land area is 0.47 percent, plantation area is 0.32 percent, settlement area is 0.53 percent, open land area is 0.51 percent, rice field area is 0.28 percent, shrub area is 0.33 percent and water body is 0.61 percent. While the validation of the AVE value for forest area is 0.92 percent, plantation area is 0.67 percent, settlement area is 1.39 percent, open land area is 1.15 percent, rice field area is 3.90 percent, shrub area is 0.64 percent and water body area is 1.89 percent, also reflecting good validation. These results fall within the acceptable deviation limit of less than 10 percent (Widiatmaka et al., 2014).

Policy Scenarios and Simulation Results of Banggai Yam Development Model

The development of Banggai yam in the Banggai Islands Regency is guided by model simulations that incorporate controlled inputs, identified as key drivers for sustainable development. Fristovana, Hubeis, and Cahyadi (2020) indicate that this scenario aims to enhance understanding of the phenomena associated with food self-sufficiency system policies. Consequently, this research is crucial for addressing food independence issues and meeting national food requirements through the utilization of local food sources. This study highlights two critical factors influencing the system: the expansion of new agricultural land and the improvement of the planting index (IP). Increased production is achievable given the availability of extensive suitable land (Firmansyah et al., 2019; Lambin & Meyfroidt, 2011). In the moderate scenario, the model assumes an annual IP increase of 1.2 and a 1.0 percent expansion of new land, while the optimistic scenario projects an IP increase of 1.5 and a 1.5 percent annual land expansion. Simulations based on these scenarios were designed to evaluate their impact on Banggai yam production. The results, comparing moderate and optimistic scenarios with current conditions, are summarized in Table 2.

TABLE 2. SCENARIO CONDITIONS WITH PLANTING INDEX DRIVERS AND NEW LANDS

Driving factors	Scenario in 2026					
	Existing	Production (tons)	Moderate	Production (tons)	Optimist	Production (tons)
Planting Index	1.00	7,191.48	1.20	8,629.78	1.50	10,787.2
New land	0.00		1.00		1.50	

The existing condition scenario reflects the average planting index without any expansion of new land in the Banggai Islands Regency, Central Sulawesi from 2018 to 2022. In contrast, the moderate and optimistic scenarios incorporate increases in the planting index and new land allocation for Banggai yam cultivation. These scenarios project future conditions aligned with expert recommendations for Banggai yam development. Model simulations begin in 2026, as 2024–2025 will focus on preparatory activities to support these scenarios. Under the moderate scenario in 2026, production is projected to increase by 8,629.78 tons, while the optimistic scenario forecasts a production increase of 10,787.2 tons.

The increase in Banggai yam production has consequently heightened overall demand in the Banggai Islands Regency, Central Sulawesi. To enhance Banggai yam exports, both moderate and optimistic scenarios are essential. Currently, exports are growing at a rate of 1.0 percent per year. The model simulation incorporates a moderate growth scenario of 4.0

percent per year and an optimistic growth scenario of 7.0 percent per year. The outcomes of these moderate and optimistic model scenarios are detailed in Table 3.

TABLE 3. SCENARIO CONDITIONS WITH EXPORT DRIVING FACTORS

Driving factors	Scenario in 2026					
	Existing	Needs (tons)	Moderate	Needs (tons)	Optimist	Needs (tons)
Export	1.00	8,536.37	4.00	8,616.79	7.00	8,697.20

Based on the results obtained in Table 3, in light of the anticipated production increase in 2026, the demand model simulation will incorporate an export boost for that year. This approach is necessary as the years 2024 to 2025 will focus on preparatory activities to support Banggai yam production, enabling effective implementation in 2026 and facilitating export growth in the same year, with projections extending to 2042. Under the moderate export scenario, an increase of 8,616.79 tons in demand for Banggai yam is expected, while the optimistic scenario predicts an increase of 8,697.20 tons in 2026. If these scenarios are executed as initially planned, they will yield a comprehensive projection of production and needs for Banggai yam in 2042.

The simulation results of production and needs scenarios for Banggai Yam, incorporating various driving factors, provide a comparative analysis of development scenarios in the Banggai Islands Regency by 2042. The production trends in scenarios 1, 2, and 3 exceed the total projected demand, indicating a production surplus in the region by 2042. To address this, exports are increased in Scenario 1. As shown in Scenario 1 (Figure 5a), which involves moderate increases in the planting index, new land, and exports, results in a surplus of 3.29 tons, with production reaching 11,846.8 tons and demand at 11,843.5 tons across 463 hectares. These findings suggest that Banggai yam production and demand will remain stable in the Banggai Islands Regency through 2042. In Scenario 2, which involves moderate increases in the planting index and new land, along with optimistic export growth, a deficit of 1,954.1 tons is projected for 2042, based on a land area of 463.2 hectares. This scenario fails to meet the total demand for Banggai yam by that year (Figure 5b). Conversely, Scenario 3, which applies optimistic assumptions across all driving variables (Figure 5c), results in a surplus of 1,248.7 tons, with production at 16,013.7 tons and demand at 14,765.0 tons, utilizing a land area of 500.9 hectares. The comprehensive results of the simulations for all Scenarios are summarised in Table 4.

TABLE 4. SIMULATION OF THE 2042 CONDITION SCENARIO

No	Policy/Scenarios	Projected in 2042			
		Production (tons)	Needs (tons)	Difference (tons)	Banggai yam land (ha)
0	Existing	8,432.6	9,947.5	−1,514.9	399.6
1	Planting Index/(M); New Land/(M); Export Increase/(M)	11,846.8	11,843.5	3.3	463.2
2	Planting Index/(M); New Land/(M); Export Increase/(0)	11,846.8	14,765.0	−2,918.2	463.2
3	Planting Index/(0); New Land/(0); Export Increase/(0)	16,013.7	14,765.0	1,248.7	500.9

Notes: M = Moderate; 0 = Optimistic

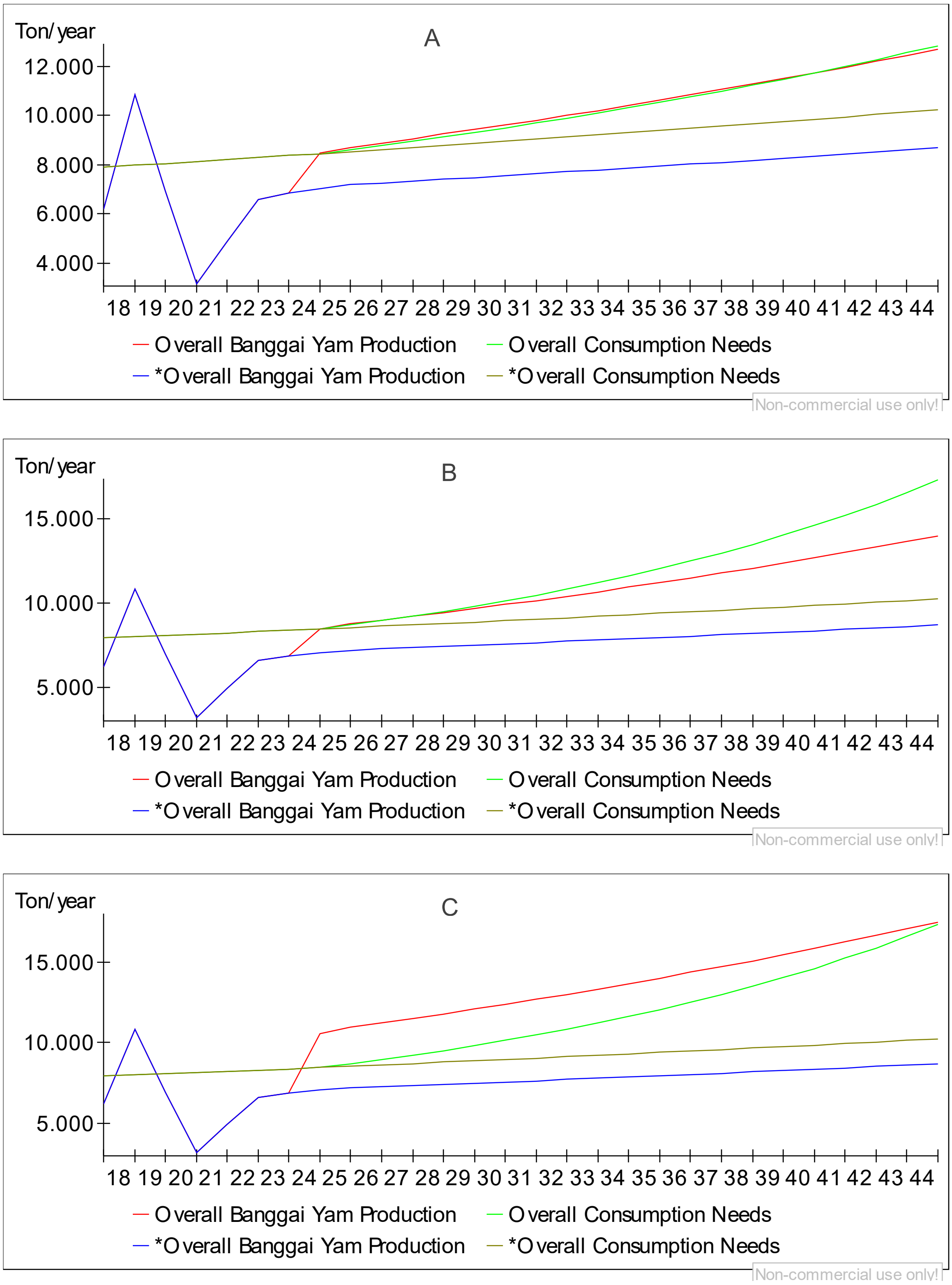


FIGURE 5. SIMULATED PRODUCTION AND NEEDS OF BANGGAI YAM UNDER SCENARIO CONDITIONS, (A) MODERATE PLANTING INDEX, ADDITION OF NEW LAND, AND INCREASE IN EXPORTS; (B) MODERATE PLANTING INDEX, ADDITION OF NEW LAND, AND OPTIMISTIC INCREASE IN EXPORTS; (C) OPTIMISTIC PLANTING INDEX, ADDITION OF NEW LAND, AND INCREASE IN EXPORTS

Furthermore, a moderate scenario model that enhances the planting index, expands new land and increases exports can establish Banggai yam as a key commodity for food independence, thereby boosting the income of farmers, particularly those cultivating Banggai yam. Consequently, food availability in the Banggai Islands Regency can be addressed by utilizing local food sources to achieve future food security. Utilizing local commodities can significantly enhance food security by reducing reliance on imported food and strengthening the local economy. Diversifying food options based on local resources can also increase the availability and consumption of a variety of nutritionally balanced and sustainable foods (Rozaki, Siregar, Pratama, & Istiyanti, 2023; Widyawati, Hanani AR, Syafrial, & Sujarwo, 2025). Additionally, Kairupan et al. (2022) note that reducing dependence on a single staple, such as rice, by incorporating various local commodities like tubers (sweet potatoes, cassava, taro), sago, bananas, and local fruits can be beneficial. This aligns with Sintiya (2023), who emphasizes the importance of simulating food self-sufficiency scenarios to support the Sustainable Development Goals (SDGs) program in Indonesia.

TABLE 5. SENSITIVITY OF VARIABLES IN THE SCENARIO

Simulation variables	Existing	Moderate (M)	Optimist (O)
Production (tons)	8,432.6	11,846.8	16,013.7
Needs (tons)	9,947.5	11,843.5	14,765.0
Banggai yam land (ha)	395.7	463.2	500.9
Simulation variables	Percentage		O/M
	Moderate	Optimist	
Production (tons)	40.49	89.90	2.22
Needs (tons)	19.06	48.43	2.54
Banggai yam land (ha)	17.07	26.60	1.56
Sensitivity Value O/M Ratio			2.00

The success of this scenario depends on collaborative strategies involving multiple stakeholders to ensure the sustainability of Banggai yam as a food source. According to Sarintang, Yasin, Syam, Adriani, and Muslimin (2021), policymakers typically evaluate models by considering their potential impacts, trends, and behavioral patterns related to the policies under consideration. Therefore, it is essential to design a policy system informed by a comprehensive understanding of overall system dynamics based on observed phenomena (Fristovana et al., 2020). Additionally, sensitivity refers to the degree to which minor changes in system inputs or parameters can influence the system's output. A system is deemed sensitive if small input changes lead to significant output variations. In the context of dynamic systems, high sensitivity indicates that slight alterations in initial conditions or parameters can result in substantial differences in the system's future behavior (Suryani et al., 2024). According to Sumargo et al. (2024), sensitivity analysis of the variables shows that a moderate scenario is optimal, with a sensitivity ratio between variables of 2:1, where the optimistic scenario policy is twice the moderate value. This ratio ensures a balanced and effective evaluation, as emphasized by Firmansyah et al. (2023). Detailed sensitivity values for the variables are provided in Table 5.

Similarly, studies by Rokhmawati, Sarasi, and Berampu (2024) and Han, Fang, Zhao, and Wang (2023) confirm a sensitivity ratio of 2.00, highlighting the moderate scenario as the most effective choice for Banggai yam development. The moderate scenario is expected to drive significant improvements in production and demand variables, offering a more efficient framework for implementing policies and strategies. By increasing the planting index and expanding new land, the scenario aims to meet food needs in the Banggai Islands Regency, Central Sulawesi, through 2042.

CONCLUSION

Existing production in this study shows that the production of Banggai yam cannot fulfill the overall demand for Banggai yam. A good scenario result in this simulation is an increase in the planting index by 1.2 percent, an increase in new land by 1 percent and an increase in exports by 4 percent from the actual conditions. This can be seen from various scenario conditions, where under moderate scenario conditions on the planting index, new land and increasing exports can meet the overall needs of Banggai yam until 2042. This scenario will be successfully if it is carried out in 2026, because it is necessary to carry out planning and preparation from 2024 to 2025, and involve many stakeholders, as implementers in the development of Banggai yam as food in Banggai Islands Regency. This research needs to be continued by determining policy direction strategies in development to avoid risk factors that affect it, especially local commodities such as Banggai yam, so that they can instead become opportunities to increase income for Banggai yam farmers and the region in Banggai Islands Regency Central Sulawesi.

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