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Analysis of Uncertainty Factors of Rice Availability in Karawang Regency Using a Dynamic System Approach

Anditania Sari Dwi Putri [1*], Annisa Indah Pratiwi [2], Annisa Nurizzati [3]
[1*,2,3] Industrial Engineering Study Program, Faculty of Engineering, Universitas Buana Perjuangan Karawang, Karawang Regency, West Java Province, Indonesia

Email: ti23.anditaniaputri@mhs.ubpkarawang.ac.id [1*], annisa.indah@ubpkarawang.ac.id [2], annisa.nurizzati@ubpkarawang.ac.id [3]

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Abstract

Karawang Regency serves as a crucial national granary, playing a vital role in supporting food security. This study analyzes how climate change, shifting agricultural land areas, productivity, and population growth impact rice availability. Additionally, it models simulations to maintain stable rice supplies using a system dynamics approach. The model was developed using Causal Loop Diagrams (CLD) and Stock Flow Diagrams (SFD), and subsequently validated through Mean Absolute Percentage Error (MAPE). The validation results showed MAPE values of 5.6% for rice production and 3.2% for rice consumption, indicating that the model is valid. Simulation results revealed that although rice production is projected to remain higher than consumption, rice availability is expected to decline until 2046. Scenario analysis demonstrated that increasing productivity has the greatest influence on improving rice availability. First scenario consisting of a productivity level of 8 tons/ha, an annual change in agricultural land area of 65 ha, a population growth rate of 0.5%, and a maximum temperature increase of 0.035°C is projected to produce approximately 539,959 tons of rice availability by 2046. The proposed model can serve as a decision support system for local governments in maintaining food security through simulation-based policy planning by incorporating the effects of flooding, paddy grain prices, rice prices, and rice distribution and supply chain dynamics.

Keywords:
Food Security; Rice Availability; Uncertainty; Dynamic System.

1. INTRODUCTION

Indonesia is the fourth most populous country in the world, with a population of 284 million people in 2025 (Anonim, 2025). Indonesia has set an ambitious vision of achieving Golden Indonesia 2045 as a United, Sovereign, Advanced, and Sustainable Unitary State of the Republic of Indonesia (Badan Perencanaan Pembangunan Nasional, 2025). The National Long-Term Development Plan (RPJPN) 2025–2045 outlines a comprehensive strategy to realize the Golden Indonesia 2045 Vision through eight national development missions. These development missions are further translated into 17 development directions (objectives), whose achievements are measured using 45 key indicators (Badan Perencanaan Pembangunan Nasional, 2025). Among the eight development missions, collectively known as the Asta Cita, the second mission focuses on strengthening the national defense and security system while promoting national self-reliance through self-sufficiency in food, energy, and water, as well as the development of the Islamic economy, digital economy, green economy, and blue economy. These eight development missions are further elaborated into 17 development directions (objectives), referred to as the 17 priority programs. The first priority program is to achieve self-sufficiency in food, energy, and water.

Food self-sufficiency is aimed at strengthening food availability, particularly through domestic production, by developing and reinforcing food production centers (Badan Perencanaan Pembangunan Nasional, 2025). The stability of rice supply is a fundamental pillar in maintaining food security at both the regional and national levels (Ramadhan & Faridatussalam, 2025). Rice is a strategic commodity that directly influences inflation and social stability (Lubis & Octavia, 2025).

West Java Province is one of the key regions contributing to Indonesia's food supply. Rice production in this province fluctuated quite significantly between 2021 and 2025. In 2021, output stood at 9,113,573 tons, which then ticked up slightly to reach 9,443,723 tons in 2022, as illustrated in Figure 1.

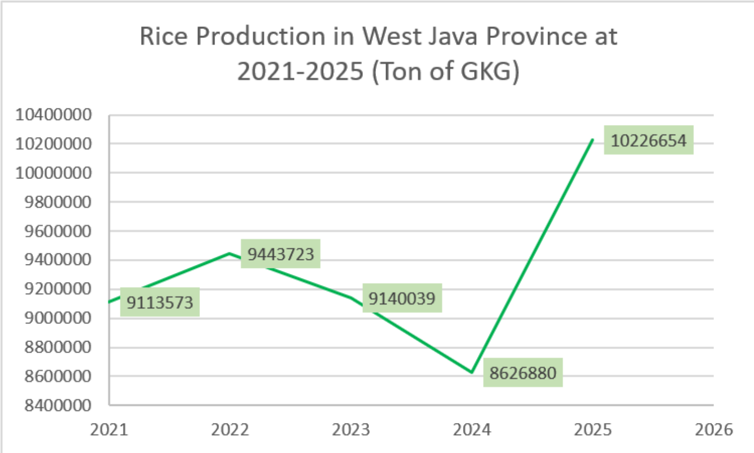

Figure 1. Rice Production in West Java Province (Central Statistics Agency, 2026)

However, this upward trend reversed in 2023, with output dropping to 9,140,039 tons of dry milled grain (GKG) and continuing its decline through 2024. The sector then bounced back in 2025, surging to 10,226,654 tons of GKG and marking the sharpest increase in the given period. These fluctuations may indicate factors that adversely affect agricultural productivity, such as changes in agricultural land area, climate change, or declining production intensity.

Rice is the primary commodity in achieving the national food self-sufficiency program. Accordingly, the potential of rice production is reflected by the extent of Permanent Paddy Field Area (Luas Baku Sawah/LBS). Based on the Decree of the Minister of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN) No. 446.1 SK-PG concerning the Determination of the National Permanent Paddy Field Area for 2024, Karawang Regency ranks second in terms of the largest permanent paddy field area in Indonesia.

Karawang Regency has long been recognized as the rice granary of West Java, although it is now also known as the regency with one of the largest industrial estates in Indonesia. According to data from the Department of Industry and Trade, there are currently 12 industrial estates in Karawang Regency. Inevitably, this development has led to changes in the extent of agricultural land within the regency. Nevertheless, land cover in Karawang Regency is still predominantly occupied by paddy fields, accounting for 52.91% of the total land area, while industrial areas account for only 2.83% (BAPPEDA Kabupaten Karawang, 2025).

Based on the foregoing, Karawang Regency remains a major rice-producing region that plays a significant role in supporting Indonesia's national food security. However, along with population growth, climate and weather change (Ruminta et al., 2024), changes in the area of agricultural land in this case can affect the area of rice plants as shown in Figure 2, akan dapat mempengaruhi ketersediaan beras atau produksi padi and changes in agricultural land area—which may affect the extent of rice cultivation areas as illustrated in Figure 2—the availability of rice and overall rice production may be significantly influenced.

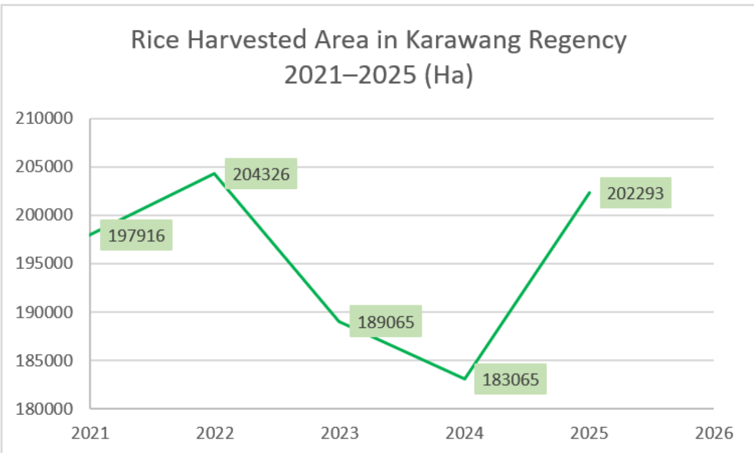

Figure 2. Rice Harvest Area in Karawang Regency (Central Statistics Agency, 2026)

Between 2020 and 2025, the harvested area for rice fluctuated, starting at 197,916 hectares in 2021 before peaking at 204,326 hectares in 2022. However, the harvested area declined to 183,065 hectares in 2024 before increasing again to 202,293 hectares in 2025, as shown in Figure 1.5. These fluctuations indicate variations in the harvested area, one of which may be attributed to changes in agricultural land area. These changes also affected rice production, which fluctuated from 2021 to 2025. In 2021, rice production reached 1,234,133 tons of dry harvested paddy (GKG). It then decreased to 1,041,530 tons of GKG in 2024 before rising again to 1,194,712 tons of GKG in 2025, as illustrated in Figure 3. This trend is consistent with the fluctuations observed in the harvested rice area over the same period.

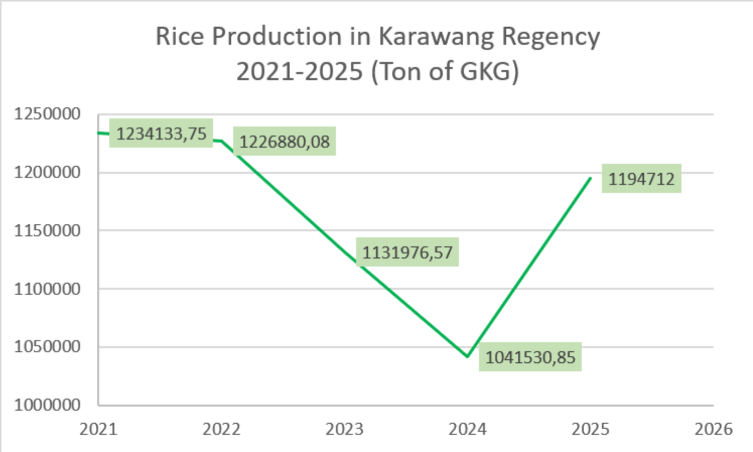

Figure 3. Rice Production in Karawang Regency (Central Statistics Agency, 2026)

Rice consumption in Indonesia remains high, driven by cultural habits where eating "rice" is considered an essential part of a proper meal. Although dietary patterns have increasingly been directed toward balanced and nutritious diets, rice continues to be the primary source of carbohydrates for most Indonesians. As shown in Figure 4, grains made up 10.9% of the average monthly food spending per capita in Karawang Regency in 2024, ranking as the third-highest expenditure category. This indicates that rice consumption remains a top priority among the people of Karawang Regency.

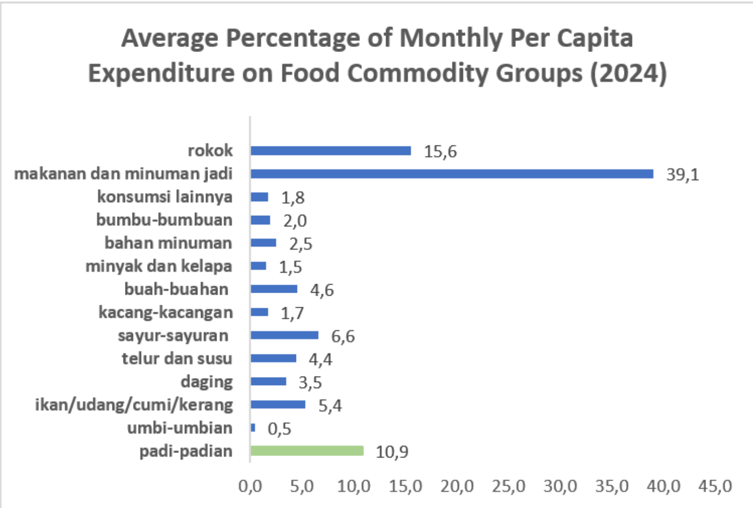

Figure 4. Average Percentage of Monthly Per Capita Expenditure on Food Commodity Groups (Central Statistics Agency, 2025)

These uncertainty factors may affect rice availability in achieving rice self-sufficiency as part of national food security. Food security is also a global issue that has attracted the attention of governments and the scientific community (Giraldo et al., 2008). This study is based on the relationship between uncertainties affecting both the supply and demand sides, which ultimately determine the level of regional ending rice stocks (Herliana et al., 2025). The dynamics between supply-side uncertainties, influenced by climate, changes in agricultural land area, and productivity (Ruminta et al., 2024) and demand-side uncertainties, driven by population growth (Sintiya, 2023) and monthly per capita expenditure (consumption) on cereals (Saputra et al., 2024) affect the stability of ending rice stocks in Karawang Regency. Climate change can affect rice production through changes in rainfall patterns, temperature, and the duration of wet and dry periods. These conditions can disrupt planting schedules, water availability, and crop growth, making rice yields more uncertain. In Karawang Regency, extreme weather conditions have been found to be associated with rice production and productivity (Buswar et al., 2025). On the other hand, the conversion of paddy fields reduces the amount of land available for rice production. A decline in paddy field area can reduce production capacity, particularly as the demand for rice continues to increase.

Given the complexity of the relationships among these variables, which are nonlinear and characterized by feedback loops, the application of the System Dynamics approach is highly relevant. System Dynamics is capable of representing the complex causal structure between the biophysical characteristics of agricultural land and socio-economic population pressures in a holistic manner (Hartono et al., 2025). This approach is appropriate because food security issues in Karawang Regency do not represent a static phenomenon but rather a dynamic system in which changes in one variable, such as a reduction in paddy field area, have long-term implications for future food stock accumulation (Putri & Syaukat, 2024). System dynamics modeling allows for the simulation of different policy options to identify the core drivers behind increased rice production and supply. Consequently, this offers a more accurate and sustainable basis for strategic planning. (Ramadhan et al., 2026).

2. RESEARCH METHOD

This study began with problem identification to capture real world phenomena, which were then analyzed by establishing the research questions, objectives, and scope to ensure a focused and relevant analysis. The theoretical framework was strengthened through a literature review, serving as the foundation for determining the required data parameters.

A Causal Loop Diagram (CLD) maps the system's conceptual framework, which is then translated into a quantitative simulation using a Stock Flow Diagram. This structured approach guarantees that the Results and Discussion are backed by a valid model, leading to Conclusions and Suggestions that offer reliable strategies for maintaining future rice supply stability. Figure 5 outlines the systematic research workflow.

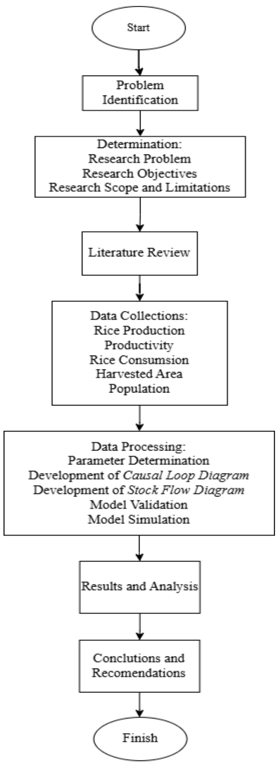

Figure 5. Research Flowchart

3. RESULTS AND DISCUSSION

The analysis of uncertainty factors affecting rice availability in Karawang Regency was conducted using a System Dynamics approach to understand the causal relationships among the variables influencing the sustainable availability of rice.

3.1. Identification of Uncertainty Factors Affecting Rice Availability in Karawang Regency

The identification of uncertainty factors was carried out through a questionnaire survey involving 30 respondents consisting of:

a. Department of Agriculture, Food Security, and Fisheries (9 respondents).
b. Regional Development Planning, Research, and Innovation Agency (15 respondents)
c. Community members (6 respondents)

The respondents were selected using purposive sampling, a sampling technique in which participants are chosen based on the consideration that they possess the knowledge, experience, and direct involvement relevant to the research problem. A total of 30 respondents was considered adequate, as it meets the minimum recommendation for assessing the reliability of questionnaire instruments (Bujang et al., 2024). The purpose of the questionnaire was to obtain assessments from respondents with relevant expertise rather than to statistically generalize the findings to the broader population. "This approach aligns with literature recommending purposive sampling to select informants who are best positioned to provide relevant insights for the study's objectives (Campbell et al., 2020).

The questionnaire was administered to evaluate the influence of uncertainty factors on rice availability in Karawang Regency using a five-point Likert scale. The indicators measured for each variable in the questionnaire are presented as follows.

Table 1. Climate Change Variable (Changes in Temperature and Rainfall)

Num	Indicator	Operasional definition
1	The impact of temperature on rice growth and productivity (Auliya et al., 2024)	Climate change refers to long-term changes in weather conditions, characterized by variations in air temperature and rainfall, which may affect rice cultivation, agricultural productivity, and rice availability (Joseph et al., 2023).
2	The impact of temperature on crop pests and diseases (Santoso et al., 2022)	
3	The impact of temperature on cropping patterns and planting schedules (Sabang et al., 2025)	
4	The impact of rainfall on the planting season and water availability (Bowden et al., 2023)	
5	The effect of climate change on rice availability (Joseph et al., 2023)	

Table 2. Changes in Agricultural Land Area Variable

Num	Indicator	Operasional definition
1	Agricultural Land Conversion Rate (Gafuraningtyas et al., 2024)	Agricultural land conversion is the change in the use of agricultural land, particularly paddy fields, to non-agricultural uses, which can affect rice production capacity and rice availability. (Mahmudah et al., 2024).
2	Impact of Agricultural Land Conversion on Rice Production (Mahmudah et al., 2024)	
3	Economic Factors Driving Agricultural Land Conversion (Gafuraningtyas et al., 2024)	
4	Effectiveness of Agricultural Land Protection Policies (Angga, 2024)	
5	Impact of Agricultural Land Conversion on Rice Availability and Food Security (Mahmudah et al., 2024)	

Table 3. Productivity Variable

Num	Indicator	Operasional definition
1	Role of Rice Productivity in Rice Availability (Anggrayana, 2025)	Agricultural productivity is the capacity of agricultural land and production factors to generate outputs in the form of paddy or rice per unit of land area. It is influenced by the use of agricultural inputs, cultivation technologies, irrigation conditions, and pest and disease infestations. (Putra et al., 2024)
2	Agricultural Production Inputs (Fertilizers and Irrigation) (Zhu et al., 2024)	
3	Production DisruptionsCaused by Pests and Diseases (Santoso et al., 2022)	
4	High Quality Seeds and Cultivation Technologies (Martinez et al., 2023)	
5	Effects of Rice Productivity on Rice Availability (Putra et al., 2024)	

Table 4. Population Growth Variable

Num	Indicator	Operasional Definition
1	Increased Rice Demand Caused by Population Growth (Wati & Faridatussalam, 2024)	Population growth is the increase in the number of people within a region over time, which leads to higher food demand, particularly for rice, and may affect the balance between rice availability and rice demand. (Wati & Faridatussalam, 2024).
2	Integration of Food Needs into Development Planning (Aziz et al., 2024)	
3	Impact of Rice Consumption on Rice Availability (Prasetyo & Fadila, 2024)	
4	Degree of Dependence on Rice (Nurhasan et al., 2024)	
5	Food Diversification and Reduced Rice Consumption (Minyiwab et al., 2024)	

The questionnaire responses were subsequently analyzed to determine the respondents' assessment of each variable. The percentage interpretation for each indicator was determined based on the following assessment criteria (Mantiri, 2025).

Table 5. Results Interpretation

Percentage	Category
84,01%-100%	Very Impoortant
68,01%-84%	Important
52,01%-68%	Moderately Important
36,01%-52%	Unimportant
20%-36%	Very Unimportant

Based on the questionnaire results, the findings are presented in Table 3.6. The results indicate that the four uncertainty factor variables have a linear influence on rice availability in Karawang Regency. Each questionnaire indicator was subsequently used as a reference for determining the polarity in the development of the Causal Loop Diagram (CLD).

Tabel 3.6. Interpretation of Variables Affecting Rice Availability

Variable	Results	Category
Climate Change	85,1%	Very Impoortant
Changes in agricultural land area	86,5%	Very Impoortant
Productivity	92,3%	Very Impoortant
Population Growth	86,8%	Very Impoortant

3.2. Causal Loop Diagram (CLD)

This stage was conducted to qualitatively identify the problem as a basis for developing a quantitative simulation model. The development of the Causal Loop Diagram (CLD) aims to map the logical interrelationships and cause-and-effect relationships among the various factors affecting rice availability in Karawang Regency, as identified from the questionnaire results. In the diagram, each relationship between variables is represented by either a positive (+) or negative (−) polarity:

a. Positive Polarity (+): Indicates a positive relationship, where an increase in one variable leads to an increase in another variable.
b. Negative Polarity (−): Indicates an inverse relationship, where an increase in one variable leads to a decrease in another variable.

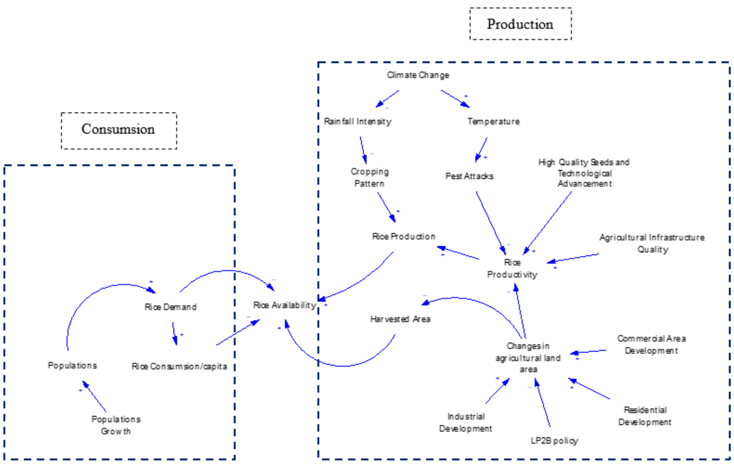

Figure 6. Causal Loop Diagram (CLD)

Figure 6, shows that rice availability depends on the interaction between consumption and production dynamics. Looking at consumption, population growth increases demand, potentially threatening rice availability unless matched by production gains. This is consistent with Wulandari and Umar (2025), whose research indicates that population expansion and consumption needs are primary drivers of future food security. Meanwhile, rice production itself is dictated by crop yields and harvested land area. Higher rice productivity and larger harvested areas lead to increased rice production, thereby helping to maintain rice availability for the population (Wulandari & Umar, 2025).

On the production side, rice availability is subject to various pressures arising from agricultural land conversion, climate change, and pest infestations. Industrial expansion, residential development, and commercial area development contribute to changes in agricultural land use, resulting in a reduction in harvested area and a decline in rice production capacity. Putra et al. (2024) reported that the conversion of paddy fields due to urbanization and regional development has a significant negative impact on rice production and availability. In addition, changes in temperature and rainfall associated with climate change can reduce rice productivity, whereas advances in agricultural technology serve as a driving factor that enhances productivity and strengthens food security. Therefore, maintaining rice availability requires the protection of agricultural land, effective control of agricultural land conversion, and the adoption of innovative and climate-adaptive agricultural technologies (Putra et al., 2024).

3.3. Stock Flow Diagram (SFD)

Based on the cause-and-effect relationships identified in the Causal Loop Diagram (CLD), rice availability results from the interaction between consumption and production factors driven by population growth, rice production, changes in agricultural land area, and climate change. The CLD illustrates the direction of influence and the feedback relationships among variables that shape the dynamics of the rice availability system. However, the CLD is unable to quantitatively represent the magnitude of changes over time or the number of resources influencing the system.

Therefore, the model must be further developed into a Stock Flow Diagram (SFD). The SFD is used to represent the relationships between stock and flow variables that determine changes in the system over time (Vanany et al., 2021). The developed Stock Flow Diagram is presented in Figure 7.

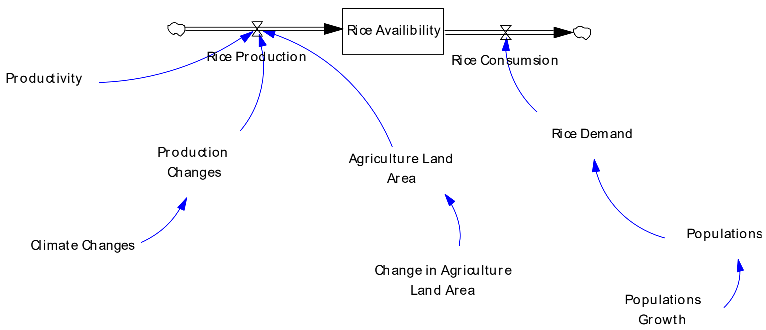

Figure 7. Stock Flow Diagram (SFD)

3.4. Validation Model

Validation Model was conducted to evaluate whether the developed model adequately represents real-world conditions. The validation process assessed the accuracy of the simulation results against actual data using the Mean Absolute Percentage Error (MAPE). The model performance was evaluated according to the criteria proposed by Lewis (1982): a MAPE value of less than 10% indicates that the model is highly accurate; a MAPE value between 10% and 20% indicates good forecasting performance; a MAPE value between 20% and 50% indicates reasonable forecasting performance; whereas a MAPE value greater than 50% indicates inaccurate forecasting (Sukartini & Moin, 2022).

Table 7. Simulation of Validation Model

Variable	Year	Actual Data	Simulation Result
Rice Production (Ton)	2021	712.690,2	665.559
	2022	708.501,3	662.764
	2023	653.696,2	657.490
	2024	601.465,5	659.256
	2025	689.925	657.926
		MAPE	5,6%
Consumsion (Ton)	2021	223.408	225 238
	2022	215.758	223 196
	2023	237.366	221 455

	2024	216.935		223 513
	2025	216.075		220 627
			MAPE	3,2%

The validation results showed that the MAPE values were 5.6% for the rice production simulation and 3.2% for the rice consumption simulation. Since both values are below 10%, the model is classified as highly accurate according to the Lewis (1982) criteria, indicating that it is suitable for simulating rice availability.

3.5. Model Simulation

At the simulation stage, the developed model was used to predict future rice availability. The model was subsequently tested under several predefined scenarios, including temperature change, population growth, rice productivity, and changes in agricultural land area.

3.5.1. Simulation of Rice Availability in Karawang Regency

The simulation was conducted to project rice availability, rice production, rice consumption, population size, agricultural land area, and temperature changes over the next 20 years.

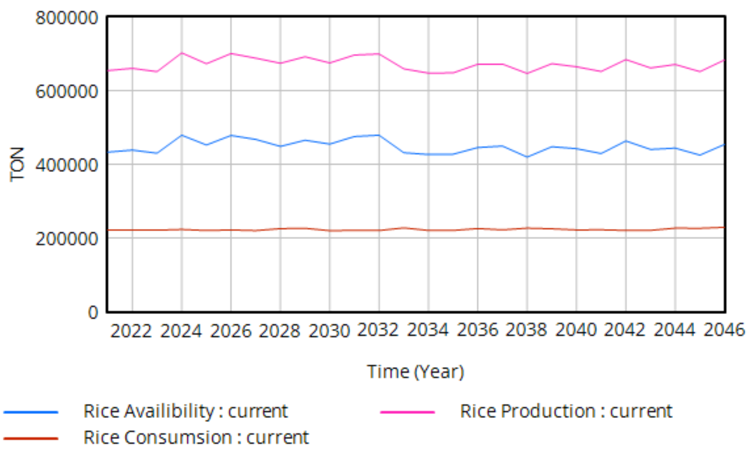

Figure 8. Rice Availability Simulation

As shown in Figure 8, rice production and rice consumption in Karawang Regency exhibit fluctuations over time, resulting in corresponding fluctuations in rice availability. The data indicate that rice production in Karawang Regency is more than twice the level of rice consumption. However, the simulation projects that rice availability will gradually decline, with rice stocks decreasing from 473,592 tons in 2021 to 428,478 tons by 2046. This indicates that rice availability is not stable due to uncertainties associated with the factors influencing the system.

In line with the objective of this study to simulate rice availability in support of food security in Karawang Regency, several policy scenarios were developed and evaluated. These scenarios include population growth control, changes in agricultural land area, improvements in rice productivity, and climate change adaptation (represented by temperature change scenarios) to identify strategies for maintaining stable rice availability in Karawang Regency.

3.5.2. Scenario Simulation

Scenario simulations were conducted to identify the factors that have the greatest influence on changes in rice availability in Karawang Regency. In addition, the simulations were used to evaluate and determine the most effective scenario for maintaining the stability of rice availability in Karawang Regency. The scenarios presented in table 8, were developed by increasing or decreasing the baseline simulation parameters to evaluate the sensitivity of the simulated variables with respect to the main output, namely rice availability.

Tabel 8. Scenario Parameters for Simulation

No	Variable	Scenario 1	Scenario 2	Scenario 3
1	Population Growth (%)	0.5	0.2	0.1
2	Changes in agricultural land area (Ha)	65	30	10
3	Temperature changing (ºC)	0.035	0.015	0.007
4	Productivity (Ton/Ha)	8	10	12

Based on the simulation results under the proposed scenarios, the projected rice availability in Karawang Regency for the year 2046 is shown in Table 9.

Tabel 3.9. Scenarion Simulation Results

No	Variabel	Scenario 1 (Ton)	Scenario 2 (Ton)	Scenario 3 (Ton)
1	Population Growth	438.771	439.426	439.645
2	Changes in agricultural land area	437.532	437.778	437..918
3	Temperature changing	444.993	445.068	445.098
4	Productivity	528.330	717.700	907.070

As shown in table 9, the most substantial increase in rice availability was observed under the rice productivity scenarios. Compared with the baseline condition, Scenario 1 increased rice availability by 23%, Scenario 2 by 68%, and Scenario 3 by 112%. However, the productivity levels assumed in Scenarios 2 and 3 (10 and 12 tons/ha, respectively) are considerably higher than historical productivity levels and therefore are unlikely to be achieved under current conditions. Consequently, Scenario 1 represents the most realistic and feasible option. A similar consideration was applied to the other variables, namely population growth, changes in agricultural land area, and temperature change.

Therefore, Scenario 1 was selected to simulate the effects of these four variables on rice availability in Karawang Regency. The simulation results are presented in Figure 9.

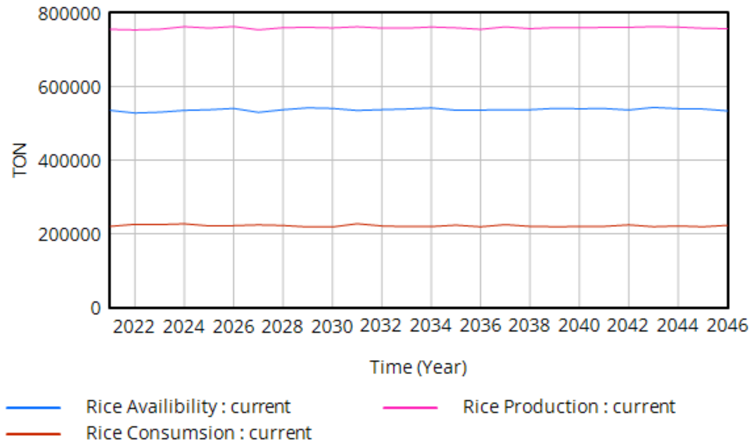

Figure 9. Simulation of Uncertainty Factors Scenario

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As shown in figure 9, the simulation to stabilize supply in Karawang Regency utilizes the variables from Scenario 1. Consequently, the projected rice availability in Karawang Regency for 2026 reaches 539,959 tons effectively doubling the total consumption. This enhanced stability is expected to secure both food security and food self-sufficiency in the region.

4. CONCLUSION

This study highlights that rice availability in Karawang Regency is shaped by four primary uncertainties: temperature fluctuations, changes in agricultural land area, crop productivity, and population growth. Questionnaire results classified all four variables as highly critical, establishing them as the foundation for developing the system dynamics model through Causal Loop Diagrams (CLD) and Stock Flow Diagrams (SFD).

Validation tests confirm the model's reliability, with MAPE values of 5.6% for production and 3.2% for consumption, demonstrating excellent accuracy for simulation purposes. Baseline results indicate that although Karawang Regency's rice production remains higher than its consumption, overall availability is projected to decrease continuously until 2046, driven by the identified uncertainty factors.

The scenario analysis indicates that increasing agricultural productivity is the single most influential driver of rice availability, surpassing the impact of population growth management, changes in farmland area, and shifting temperatures. Considering historical conditions and implementation feasibility, Scenario 1—which combines an increase in rice productivity to 8 tons/ha, control of agricultural land conversion to 65 ha/year, a population growth rate of 0.5%, and a temperature increase of 0.035°C—was identified as the most realistic and feasible strategy. The implementation of this scenario is projected to increase rice availability to approximately 539,959 tons by 2046, thereby helping to maintain stable rice availability

Recomendation

a. Improving rice productivity is an important priority, as the simulation results show that productivity has the greatest influence on rice availability. This can be supported by the use of improved seed varieties, balanced fertilizer application, appropriate agricultural machinery, and regular assistance for farmers.

Extension services should also focus on practical support so that farmers can apply these improvements effectively in the field. (Martinez et al., 2023; Santoso et al., 2022; Wulandari & Umar, 2025).

b. Protecting paddy fields through the implementation of Sustainable Food Agricultural Land (LP2B) is also important to maintain the production capacity of the region. This requires not only designating LP2B areas but also ensuring that the policy is implemented consistently. Regular updates of LP2B data and maps, monitoring of land-use changes, and periodic evaluation can help prevent the conversion of protected agricultural land. Coordination among relevant local government agencies is also needed to strengthen supervision and enforcement (Angga, 2024; Gafuraningtyas et al., 2024; Mahmudah et al., 2024).
c. Adapting rice production to climate change should be carried out by considering the conditions faced by farmers in the field. The use of climate-resilient varieties, adjustments to planting schedules based on seasonal and climate information, and more efficient irrigation can help reduce the risks associated with changing weather conditions. These efforts should be accompanied by better access to climate information and technical assistance for farmers (Bowden et al., 2023; Joseph et al., 2023; Ruminta et al., 2024; Saputra et al., 2024).
d. Balancing population growth with rice demand is necessary to maintain a reasonable balance between food supply and consumption. Population projections and changes in rice consumption should therefore be considered in regional food planning. Strengthening population management and promoting more diverse food consumption can also help reduce pressure on rice demand (Herliana et al., 2025; Prasetyo & Fadila, 2024; Ramadhan & Faridatussalam, 2025).
e. Strengthening collaboration among stakeholders is needed because maintaining rice availability cannot be addressed by the government alone. Local governments, farmers, universities, businesses, and communities can work together through coordination forums, farmer assistance, pilot projects, and the application of research-based innovations. Regular evaluation of these activities is important to determine whether the interventions are actually improving rice production and availability (Aziz et al., 2024; Giraldo et al., 2008; Vanany et al., 2021)

Future Research Directions

Future research may further develop the system dynamics model by incorporating additional variables that were not included in the present study, such as the impacts of flooding, paddy prices, rice prices, and interregional rice distribution, including both inflows and outflows of rice (Wajdah et al., 2024).

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