SEMARTANI-3
ISSN: 2833-5376
Volume 03 Number 03 (2024)
Impact Factor: 9.51
SJIF (2023): 3.916

www.inter-publishing.com

Article

Policy Analysis on Increasing Rice Production in Lampung Province Using a System Dynamics Model Approach

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Abstract: Lampung Province has an important role in fulfilling the need for rice as a staple food in Indonesia. Lampung is ranked sixth as a national rice producer with production reaching 2,604,913 tons. Problems in the production subsystem cause a decrease in rice stocks which will have an impact on not fulfilling the need for public rice consumption. The shift in the use of paddy fields from agriculture to non-agricultural sectors is one of the causes of the decline in rice production. This is further exacerbated by the low planting rate and rice productivity that has not reached the optimal level. Based on this phenomenon, this study aims to develop and validate a system dynamics model to design strategies to increase rice production in Lampung Province. The model in this study has been tested for validity using the Root Mean Square Percentage Error (RMSPE) calculation method. The test results state that the difference between the values calculated by the model and the actual values is greater than 5% and smaller than 10%. Therefore, it can be said that the modeling is valid and accurate. The results of system modeling with the design of scenarios 1, 2, and 3 at moderate and optimistic levels concluded that an increase in rice production can be achieved in the optimistic scenario 3, namely an increase in rice productivity to 5.73 tons/hectare (optimistic level).

Keywords: Dynamical system, Lampung Province, Production improvement

Citation: April Lia Sahidah1, Desi Melenia, Tiara Indah, Vitta Herina. Policy Analysis on Increasing Rice Production in Lampung Province Using a System Dynamics Model Approach. International Journal of Biological Engineering and Agriculture 2024, 3(3), 298-307

Received: 12th July 2024
Revised: 15th July 2024
Accepted: 21th July 2024
Published: 24th July 2024

1. Introduction

Food security for a country is an urgent matter, especially for a country with a very large population such as Indonesia, which is estimated to reach 220 million people in 2020 and is projected to become 270 million people in 2025 [1]. The main parts of food security are food availability, food supply, and food quality and safety. Through the effective cooperation of these three subsystems, food security can be achieved. Rice is still the number-one most important food in Indonesia. This condition is due to the fact that the carbohydrate needs of most people in Indonesia, including the people in Lampung, are still met by the staple food, namely rice. Lampung Province is part of one of the provinces that contributes to the fulfillment of food availability to supply the need for consumption of rice throughout Indonesia and is in sixth place with a total production of 2,604,913 tons. Based on the total production figure, it means that Lampung Province contributes 4.78% of the total production area of paddy rice in Indonesia, which is 55,160,548 tons [2]

It is known that rice productivity in Lampung is supplied by 15 districts and cities. Problems in the production subsystem cause a decrease in rice stocks, which will have an impact on not fulfilling the rice consumption needs of the community. One of the factors causing the decline in rice production is the change in the use of paddy fields that are converted to non-agricultural functions. Lampung Province Regional Regulation No. 17 of 2013 concerning Sustainable Food Agricultural Land (LP2B) is one of the efforts

mobilized to maintain the sustainability of agricultural land, especially paddy fields, in the hope that existing rice fields will not again experience a reduction due to land conversion. Based on data sources from the [3], rice production in Lampung in 2022 increased by 7.08%, or 2.66 million tons of GKG, from the total production in 2021 of 2.49 million tons of GKG. The increase in rice paddy production in Lampung Province is proportional to the increase in rice harvest area, namely 489.57 hectares in 2021, which increased by 5.58%, or 516.91 thousand hectares in 2021. Despite the increase in rice production figures in Lampung Province, this was also accompanied by an increase in the population each year. Along with the increase in population growth, the demand for rice consumption will also increase. To be able to fulfill the food needs of the population and continue to contribute to supporting national food needs, increasing rice production in Lampung Province is very important. Based on this phenomenon, it is necessary to have an approach in the form of a dynamic system in order to consider the right way to increase rice production in Lampung Province in the future.

Dynamic Model Simulation has proven to be an effective evaluation tool and modeling tool for complex stochastic systems in the real world. [4] used a dynamic simulation of rice stocks with the aim of supporting the creation of food security in Bali Province. The results of his research are in the form of simulations to overcome the rice stock deficit. One policy option that can be done is to increase rice productivity with a minimum target of 6.7148 tons per hectare (optimistic scenario 1) and/or increase planting intensity with a minimum target of 2.0622 (optimistic scenario 3). According to research by Budiawan, Arvianto, & Hadi (2020), the results of the simulation carried out show that with a percentage of 58%, the amount of rice production can meet the community's rice needs until year 7, while for the next year, an increase in rice paddy increase policy is needed to be 60% to be able to meet rice needs until year 24. By considering the facts, the existing problems, and the importance of policies in preventing a decline in rice production in Lampung Province in the future, a study is needed to obtain an effective policy strategy for increasing rice production. This effort aims to find solutions that can increase rice production in accordance with the needs of the community in the next 15 years (2023-2038) by optimizing the use of available resources in order to achieve sustainable food security

2. Materials and Methods

Research location This research was conducted at Plant Laboratory 1, Department of Crop Cultivation, Politeknik Negeri Lampung, from March to April 2024.

Materials and Tools Data collection as research material in the development of a dynamic system model to see the availability of rice stocks in Lampung Province was carried out in Bandar Lampung, Lampung Province. Research on the development of the dynamic system model began in June and was completed in August 2023.

Tools and Materials The instrument used in this research is a Lenovo laptop with the following specifications: 4GB of Intel RAM, Microsoft Excel and Word 2010 programs, and Powersim Studio 10.

Model Development The construction of a model for rice production in Lampung Province includes a production submodel that shows how much rice is owned. Secondary data collection in the form of time series data, regulations, information, and government policies pertaining to the rice stock system from owned production is used for model development. The data were gathered from the Central Bureau of Statistics (BPS), scientific journals, the Lampung Province Agriculture Office, and the Ministry of Agriculture of the Republic of Indonesia (Kementan RI). The model output predicts rice production in Lampung Province from 2023 to 2038. This study's model was developed using the following time series data: 1) rice field area; 2) rice harvest area; 3) rice productivity; and 4) harvested dry grain (GKP).

Validation of the Dynamic System Model Validation aims to ascertain whether the model has correctly described the real system. Validation is carried out by utilizing existing data and simulation results from 2018 to 2022. The validation method uses the calculation of root mean square percentage error (RMSPE) based on research [4]. The lower the RMSPE value, the higher the validity value of the model. Equation 1 describes the RMSPE method used.

$$RMSPE = \sqrt{\sum((Xs-Xe)/Xs)^2} \times 100\% \quad \text{.....(1)}$$

Description: Xs = simulation result data Xe = existing data n = number of data points/period. The interpretation of the final RMSPE data is as follows: Error < 5% = very valid describing existing conditions 5% < Error < 10% = valid in describing existing conditions Error > 10% = not valid in describing existing conditions

Implementing the research This research was carried out in stages in accordance with the system dynamics model development method, which includes problem identification and research objectives, model conceptualization, model formulation, model validation, scenario simulation, and scenario-based policy recommendations.

2. Results and Discussion

Based on the data in Table 1, rice production in Lampung Province has fluctuated in the last five years. The decline in rice production figures is due to a decrease in the number of harvest areas and the productivity of rice planted. In 2019, the rice harvest area in Lampung Province was 464.10 thousand hectares, then decreased by 47.84 thousand hectares, or 9.34%, compared to 2018 production. The decrease in the harvest area is directly proportional to the decrease in the amount of rice paddy production in Lampung Province in the same year, which only reached 2.16 million tons of milled dry grain (MDG), a decrease of 0.32 million tons, or 13.04%, when compared to 2018. Rice production decreased again in 2021 due to a decrease in the number of harvest areas.

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Table 1. Harvested Area, Production, Productivity, and Population of Lampung in 2018-2022

Year	Harvested Area (Ha)	Production (Ton)	Productivity (Ton/Ha)	Total Population
2018	511.940,93	2.488.641,91	4,86	8.370.485
2019	464.103,42	2.164.089,33	4,66	8.447.737
2020	545.149,05	2.650.289,64	4,86	9.007.848
2021	489.573,23	2.485.452,78	5,08	9.081.792
2022	516.910,01	2.661.362,81	5,15	9.176.546

Source : (Central Bureau of Statistics, 2022)

Dynamical System Model of Rice Production

This research develops a dynamical system model for rice production. The model is based on the relationships depicted in the causal loop diagram (CLD), and is also equipped with a feed back loop mechanism. The model is then simulated using inputs from several variables that affect the increase or decrease of rice production. To realize this conceptual model in a computer-modeled form, a computer-based modeling tool called Powersim Studio was used. This approach uses a stock flow diagram, The previous studies that used research with this method are (Ardi dan Leisten, 2015).

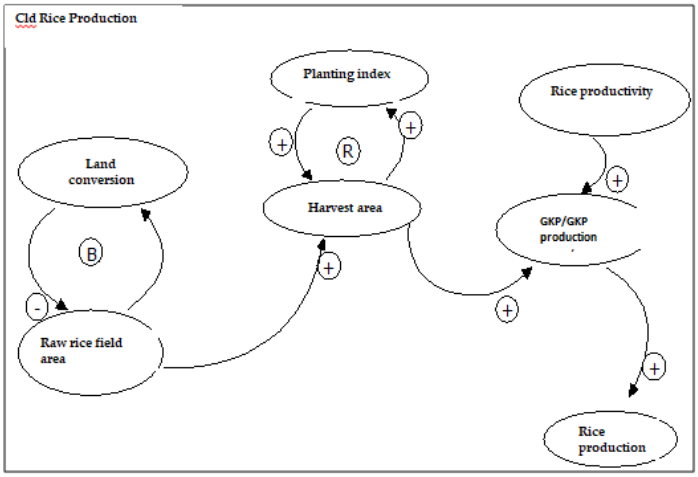

Figure 1. Causal loop diagram (Cld) of the rice production subsystem in Lampung Province. (CLD), (B) = positive loop (increase) = (R) negative loop (decrease)

Model Formulation Model formulation is the translation of the system in the form of stock and flow diagram equations simulated through PowerSim 2010 Express software. The rice production model is shown in Figure 2, while the mathematical equations of the rice production model can be seen in Table 2

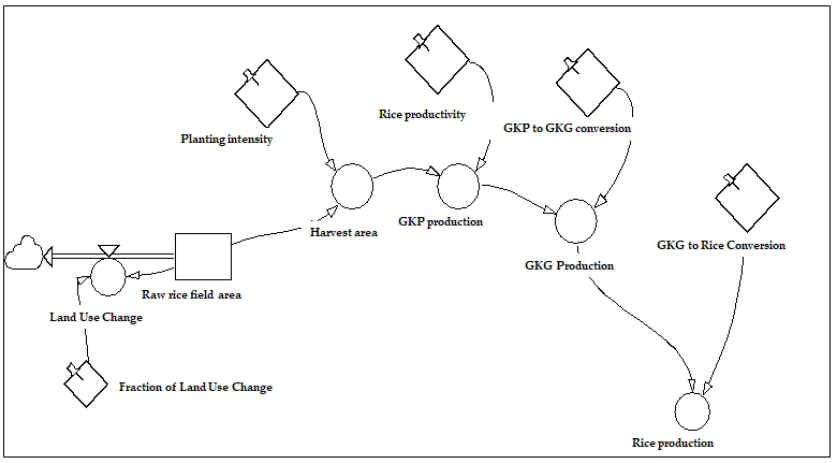

Figure 2. Stock and flow diagram of rice production model of Lampung Province

Table 2. Mathematical Equation of Lampung Province Rice Stock Model

Variables	Mathematical Equation	Unit
Rice Production	'GKG to Rice Conversion'*'GKG Production'	Ton
GKG to Rice Conversion	63,82	%
GKG Production	'GKP to GKG conversion'*'GKP production'	Ton
GKP to GKG conversion	82,92	%
GKP production	('Rice Harvest Area'*'Rice Productivity')	Ton
Rice Productivity	4,92	Ton/Hectare
Rice Harvested Area	'Cropping Intensity'*'Rice Field Size'	Hectare
Rice Planting Intensity	1,43	Dimensionless
Raw Rice Field Area	364.156	Hectare
Land Use Change	Fraction of Land Use Change'*'Rice Field Size'	Hectares/Year
Fraction of Land Use Change	0,67	%/ Year

Model Model Validation

A system dynamics model can be used as the basis for policy analysis tools if the model has been verified both logically and theoretically. The model in this study has been tested for validity using the Root Mean Square Percentage Error (RMSPE) calculation method. The test results state that the difference between the values calculated by the model and the actual values is greater than 5% and smaller than 10%. Therefore, it can be said that the modeling is valid and accurate. The results of the validity test of the harvest area and rice production are presented in Table 3. The RMSPE validation test value for the harvest area variable is 5.76 percent, and the RMSPE validation test result for the rice production variable is 7.77 percent.

Table 3. Validation Test of Harvested Area, and Rice Production in Lampung Province

Year	Harvested Area		Rice Production	
	Original Data	Simulation	Original Data	Simulation
2018	511940,93	517229,44	2.488.642	2.546.010
2019	464103,42	508448,26	2.164.089	2.502.983
2020	545149,05	449894,81	2.650.290	2.460.682
2021	489573,23	491446,59	2.485.453	2.419.097
2022	516910,01	483141,14	2.661.363	2.378.214
Root Mean Square Percentage Error (RMSPE) Value	5,76%		7,77%	

Policy Scenarios and Simulation Results of Rice Production Model

Arable land area and the carrying capacity of arable land are important factors affecting rice production. The more land owned, the greater the potential to increase production rates [7];(Pudaka, dkk 2018).This is also in line with the research of Sukmayanto et al. (2022), which states that the area of cultivation has a significant effect on increasing rice production. Based on the results of these studies, the scenarios simulated in this study include reducing land conversion, increasing rice productivity, and increasing cropping intensity. The determination of the scenario run in this study refers to research [4]**.** There are two categories of scenarios, namely the moderate category and the optimistic category. In the moderate category, an increase of 8.16 percent is assumed from the current condition. Meanwhile, in the optimistic category, it is assumed that there will be an increase with a value of 16.325 from the current condition. This assumption is based on the efforts made by the Lampung Provincial Government, which have succeeded in increasing rice production in 2022.

Table 4. Scenario Details

Scenario	Policy	Future condition	
		Moderate	Optimistic
0		Existing Condition	
1	Reduction in the rate of land conversion	Decrease in the rate of land conversion by 8.16% from 0.67% (existing conditions) to 0.62%	Decrease in land conversion rate by 16.32% from 0.67% (existing condition) to 0.56%.
2	Increased rice planting intensity	Increased rice planting intensity by 8.16% from 1.43 (existing condition) to 1.55.	Increased rice planting intensity by 16.32% from 1.43 (existing condition) to 1.66.
3	Increased rice productivity	Increased rice productivity by 8.16% from 4.92 tons/Ha (existing conditions) to 5.32 tons/Ha.	Increased rice productivity by 16.32% from 4.92 tons/Ha (existing conditions) to 5.72. Ton/Ha

Scenario 0 (existing conditions)

Scenario 0 is used to predict the future conditions of paddy field area, rice production, and rice stocks by considering the current parameter conditions. Scenario 0 serves as a reference point for developing subsequent scenarios. The results obtained from scenario 0 show that the production of GKG in 2024–2028 is smaller. Production of rice with the highest value occurred in 2018 at 1,356,489.71 tons, while the decline in 2038 was 1,182,715.89 tons. The decline in production is due to the factor of land use change, which results in the reduction of raw rice fields. The reduction of paddy fields will certainly result in a decrease in rice production and a decrease in rice stocks in Lampung Province in the future (Figure 3). The low cropping intensity of 1.43 also resulted in low rice production in Lampung Province. The frequency of planting is not high because the land for rice in Lampung Province is partly non-irrigated, so rice planting can only be done once a year. This problem is a challenge for the authorized agencies to be able to increase the frequency of planting, especially in rainfed rice fields.

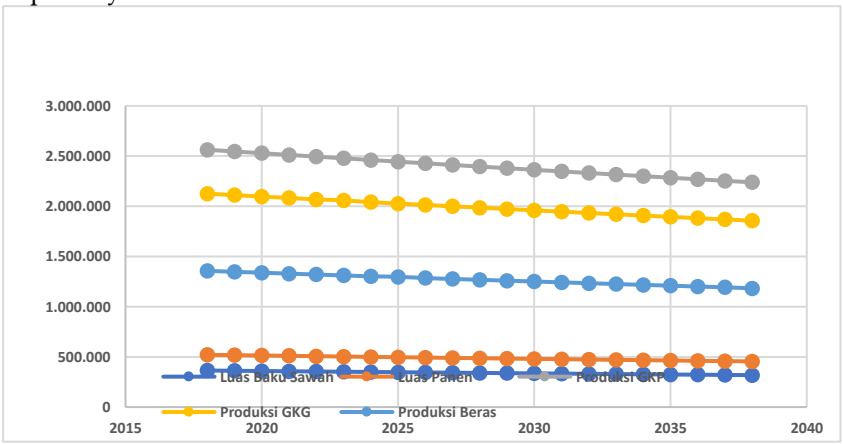

Figure 3. Simulation results of scenario 0 (existing conditions)

Scenario 1 (Increasing Rice Production through Reducing the Rate of Land Conversion)

The increase in population in Lampung Province is accompanied by an increase in the need for rice and land for infrastructure. This has led to the diversion of agricultural land use to non-agricultural sectors such as industrial uses, housing, health facilities, roads, and so on. This can result in a tendency to convert agricultural land into land for housing and business purposes. Asnawi (2022) stated that some of the main causes for farmers in Lampung to convert paddy fields to non-rice fields are lack of irrigation water, high land selling prices, and higher prices for substitute commodities, as well as pest attacks and drought. The factor of high land selling prices makes farmers sell their paddy fields to outsiders, which are then slowly converted to non-field land or agricultural fields and gradually become industrial buildings, shops, or housing.

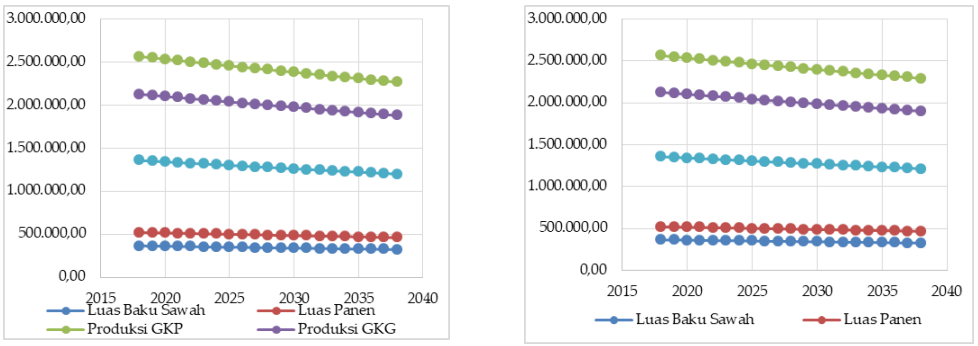

Figure 4. (a) Moderate scenario simulation results and (b) optimistic scenario 1 simulation results.

The increase in population in Lampung Province is accompanied by an increase in the need for rice and land as infrastructure. This causes the diversion of agricultural land use to the non-agricultural sector for industrial purposes, housing, health facilities, roads, and so on. This can encourage people to convert agricultural land into land for housing and business purposes. Asnawi (2022)stated that some of the main causes for farmers in Lampung to convert paddy fields to non-rice fields are lack of irrigation water, high land selling prices, and higher prices of substitute commodities, as well as the attack of rice pests and drought. The factor of high land selling prices makes farmers sell their paddy fields to outsiders, which are then slowly converted to non-field land or agricultural fields and gradually become industrial buildings, shops, or housing.

Scenario 2 (Increased Planting Intensity as an Effort to Increase Production)

Scenario 2 in this paper is designed as an attempt to increase rice production by increasing planting frequency. Research Sintiya (2023) states that the option of increasing rice production factors is the best scenario for increasing rice stocks. In addition to land area, planting intensity is what determines rice production. Planting intensity is the frequency of rice planting in one year. Some factors that affect planting intensity include water availability, farmer capital, and climate. In Lampung Province, the intensity of rice planting is still relatively low because planting is only done once a year in the rainy season, especially in rainfed rice fields. In scenario 2, the intensity of planting was increased to 1.55 (moderate level) and 1.66 (optimistic level). The simulation results of scenario 2 can be seen in Figure 5.

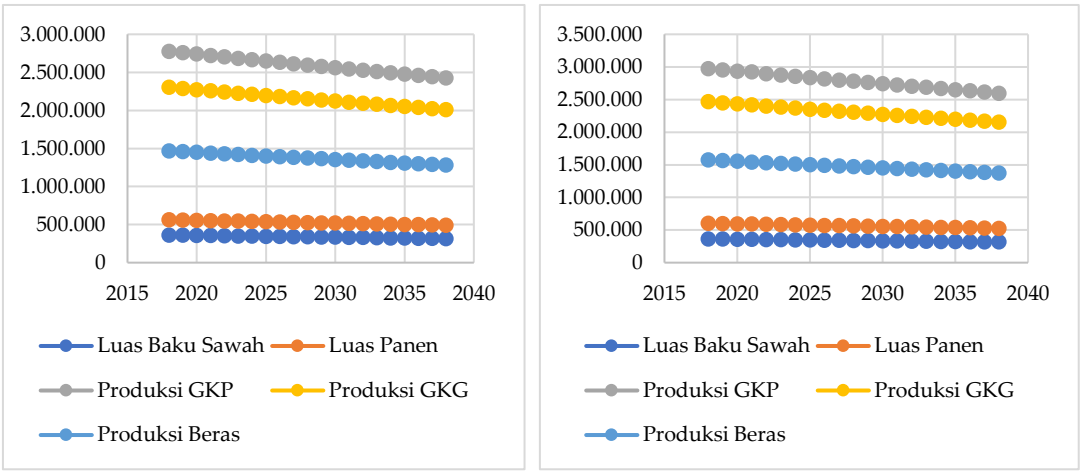

Figure 5. (a) Moderate scenario 2 simulation results and (b) optimistic scenario 2 simulation results.

The simulation results of scenario 2 with a moderate level show that the rice production figure in 2038 is estimated at 1,284,132.60 and in the optimistic scenario 2 at 1,375,264.60 tons, which is greater than the existing data of 1,182,715.89 tons. The resulting increase reached more than 1 million tons, both in the moderate scenario 2 and the optimistic scenario 2. This shows that scenario 2 can be pursued to increase rice production in Lapung in the future.

Scenario 3 (Efforts to Increase Production through Increased Rice Productivity)

The design of scenario 3 is an attempt to increase rice production with a strategy to increase rice productivity. Aprillya & Suryani (2023)stated that important factors that will reduce rice productivity include the seeds planted, irrigation, fertilizer application, and the intensity of pest attacks. Increasing rice productivity is a factor that affects the increase in production more than the expansion of planting land [13]. Based on BPS data, the highest rice productivity in Lampung Province is 5.15 tons/ha. The rice productivity used in the existing data is 4.92 tons/ha. In this scenario, rice productivity will be increased to 5.32

tons/hectare (moderate level) and 5.73 tons/hectare (optimistic level). The simulation results of scenario 3 can be seen in Figure 6.

The design of scenario 3 is an attempt to increase rice production with a strategy to increase rice productivity. Aprillya & Suryani (2023) stated that important factors that will reduce rice productivity include the seeds planted, irrigation, fertilizer application, and the intensity of OPT (plant disturbing organism) attacks. Increasing rice productivity is a factor that affects the increase in production more than the expansion of planting land (Arifin, Arsyad Biba, Azisah, Sadat, & Mardiyati, 2022). Based on BPS data, the highest rice productivity in Lampung Province is 5.15 tons/ha. The rice productivity used in the existing data is 4.92 tons/ha. In this scenario, rice productivity will increase to 5.32 tons/hectare (moderate level) and 5.73 tons/hectare (optimistic level).

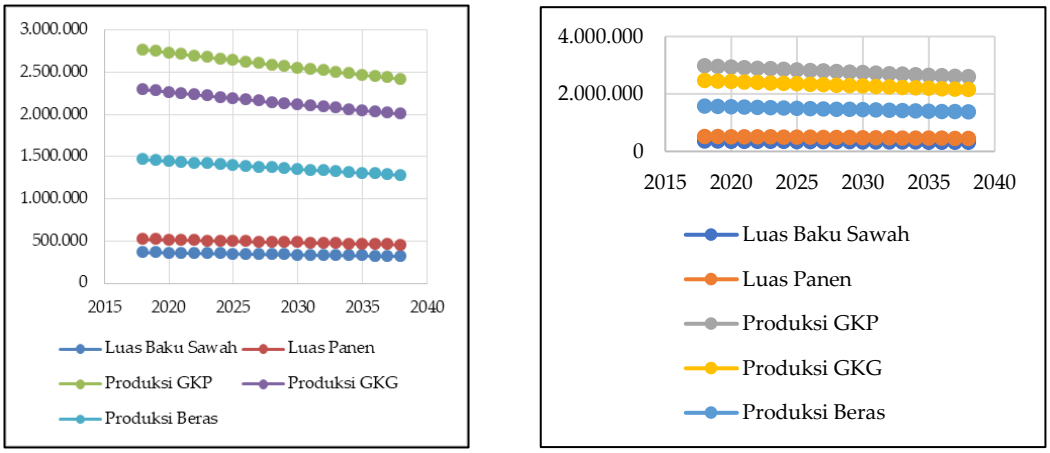

Figure 6. (a) Moderate scenario 3 simulation results and (b) optimistic scenario 3 simulation results

Figure 6 shows that rice production in 2038 from moderate simulation results is 1,280,409.66 tons, and the optimistic is 1,376,681.06 tons. Scenario 3 at the moderate and optimistic levels shows that although there is a decrease in land conversion characterized by a steep slope of the graph, the rice production graph remains sloping. Therefore, it can be stated that productivity greatly affects rice production. The results of scenario 3 at an optimistic level show the success of the Lampung Provincial government in increasing rice production so as to strengthen food security conditions. Efforts to optimize rice productivity can be carried out by the government by making policies, including improving irrigation channels, providing fertilizer subsidies, superior seed assistance, pesticide assistance, capital assistance, implementing the jajar legowo planting system, and being equipped with massive assistance from agricultural extension officers and the Agriculture Office or the Food Crops Office.

Assessment of the Most Effective Scenario

In this research, a dynamic model system has been created with various conditions, namely scenario 0, scenario 1, 2, and 3 at moderate and optimistic levels, which are used to predict the conditions of raw area, harvest area, harvest production, and rice production in 2038. According to Table 5, the largest harvest area is achieved in optimistic scenario 2 by increasing the intensity of rice planting in Lampung Province. Increasing harvest area corresponds to an increase in rice paddy yield and rice production in 2038. However, the most rice paddy and rice production were achieved in the optimistic scenario 3 by improving rice productivity. This demonstrates that increasing rice productivity is the most effective long-term approach and policy for increasing rice production. To boost rice productivity, the government can implement policies such as improving irrigation facilities, providing fertilizer subsidies, superior seed assistance, pesticide assistance, implementing

the jajar legowo planting system, and providing massive intensive assistance from agricultural extension workers and related agencies.

Table 5. Recapitulation of Model System Results in 2038

Type	Predictions for 2038			
	Raw land (ha)	Harvest area (ha)	Rice Production (tons)	Rice production (tons)
Scenario 0	318.042,52	454.800,80	2.238.711,44	1.182.715,89
Scenario 1 moderate	321.758,12	460.114,11	2.264.865,71	1.198.556,60
Scenario 1 is optimistic	325.469,11	465.420,83	2.290.987,51	1.212.380,15
Scenario 2 moderate	318.042,52	492.965,90	2.426.575,34	1.284.132,60
Scenario 2 is optimistic	318.042,52	527.950,58	2.598.783,91	1.375.264,60
Scenario 3 moderate	318.042,52	454.800,80	2.419.540,24	1.280.409,66
Scenario 3 is optimistic	318.042,52	454.800,80	2.601.460,56	**1.376.681,06**

3. Conclusions and Policy Recommendations:

The validation tests confirm the reliability of the system dynamics model, making it a viable tool for formulating policies aimed at boosting rice production in Lampung. The model outlines three strategic scenarios for enhancing rice output: mitigating land conversion, boosting planting intensity, and improving rice productivity. Among these, the scenario focusing on elevating rice productivity to an optimistic level emerges as the most effective, yielding the highest production increase. Policy recommendations should prioritize implementing measures that enhance productivity, as this approach offers the greatest potential for achieving substantial improvements in rice production.

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