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Dynamic Model for Food Security to Realize Food Sovereignty: Case Study in Bantul Regency of Yogyakarta Special Region

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ABSTRAK

Peningkatan jumlah penduduk harus diimbangi dengan peningkatan produksi pangan sehingga ketahanan pangan daerah dapat terjaga. Permasalahan ketahanan pangan tidak akan teratasi jika tidak menyelesaikan akar permasalahan yaitu alih fungsi lahan pertanian dan keterpurukan petani. Tujuan utama kajian ini adalah merancang model dinamis pertanian pangan berkelanjutan. Metode yang digunakan dalam mencapai suatu pendekatan dengan sistem dinamis. Analisis kebutuhan, perumusan masalah, identifikasi sistem, pemodelan sistem, validasi model, dan implementasi merupakan tahapan penyelsaian masalah dengan metode pendekatan sistem. Perangkat lunak Powersim studio digunakan untuk menganalisis sistem yang terjadi dan perilaku model. Berdasarkan hasil prediksi model, skenario tanpa pengendalian pada tahun 2021 Kabupaten Bantul terjadi kekurangan beras sebesar 1.925 ton. Skenario moderat dengan kebijakan pengendalian 50% alih fungsi lahan sawah menyebabkan neraca beras menjadi kurang 1.001 ton. Skenario optimis, pengendalian alih fungsi lahan sawah 50% dan diversifikasi pangan diperoleh neraca beras berlebih 5.460,24 ton pada tahun 2030.

Kata kunci: Diversifikasi pangan, Powersim; Neraca beras, Sistem dinamis, Yogyakarta

ABSTRACT

The increased populism should be offset by increased food production; thus, the region's food security can be maintained. Food security will not be resolved if it does not solve the root of the problem, namely the farmers' deterioration and the agricultural land conversion. The primary purpose of this study is to design a dynamic model of sustainable food farming—the methods used in achieving an approach with a dynamic system. Needs analysis, problem formulation, system identification, system modeling, model validation, and implementation are the stages in problem-solving with the systems approach method. The Powersim Studio software analyzes the system and views model behavior. Based on the predicted results, in 2021, Bantul Regency experienced a deficit rice of 1,925 tons without control efforts. A pessimistic scenario with a control policy of 50% of the rice field function transfer rate caused the rice balance sheet to be a deficit of 1,001 tons. Optimistic scenario, control of paddy field conversion 50% of the transfer rate and food diversification obtained rice balance with a surplus of 5,460.24 tons by 2030.

Keywords: Dynamic system, Food diversification, Powersim, Rice balance, Yogyakarta

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1. Introduction

Indonesia's population in 2018 reached 265 million people. From 2009 to 2018 addition of Indonesia's population continued to increase with an average population growth rate of 1.32% (BPS, 2018). According to Khairati and Syahni (2016), if population growth is 1%, the population's demand for grains will increase by 8%. According to Ichwandi (2014), food security will not be realized if the root of the problem has not been appropriately resolved. The welfare of farmers and the conversion of agricultural land will not be realized. One of the sources of conversion of agricultural land is the acquisition of agricultural land on a large scale by entrepreneurs. The World Food and Agriculture Organization (FAO) said that large-scale land acquisitions in Latin Africa, America, Central Asia, and Sutsoutheastsia were the latest topics of conversation. Land The land is currently pretty for international investors, and they want to control thousands of hectares of land (FAO, 2019). Bantul Regency is one of the regencies in the Special Region of Yogyakarta Province, which continues to experience the conversion of paddy fields into non-paddy fields. In 2013–2017 Central Bureau of Statistics (BPS) said that there had been a conversion of paddy fields worth 1.85% with a change in paddy fields from 15,471 ha to 15,184 ha.

Meanwhile, in the same year, the area of non-paddy fields in Bantul Regency has increased by 5.85% with the addition of non-paddy fields from 21,089 ha to 22,324 ha. The population of the Bantul Regency in 2018 was recorded at 1,006,692 people (BPS, 2018). An increase in food production should accompany the increase in population to fulfill food needs.

According to Law No. 18 of 2012, food security is a condition for the fulfillment of food for the state to individuals. Meanwhile, food sovereignty is the right of the state and nation to independently determine food policies that guarantee the right to food for the people. One of the factors that can threaten food sovereignty is island conversion. It is necessary to conduct a study to build a dynamic model of Sustainable Food Agricultural Land (LP2B) to realize food security. It is hoped that this study can be input for the government in managing agriculture and realizing food sovereignty. Therefore, this study aims to design a dynamic model of sustainable food agricultural land to realize food sovereignty based on the protection of sustainable food agricultural land. This study is expected to design a dynamic model of sustainable food farming. The results of this study can be used to apply the concept of Sustainable Development Goals to the second goal, namely overcoming hunger.

2. Materials and Methods

The study was carried out in July–October 2020. The study was carried out in Bantul Regency, Yogyakarta Special Region. The tools used in this study are laptops equipped with Microsoft Office 2010 version and Powersim Studio version 10. The materials used are population data of Bantul Regency, Special Region of Yogyakarta, data on rice demand, rice supply, land need, paddy field area, productivity, and rice production in Bantul Regency.

The method in this study uses a dynamic model approach. The approach using a dynamic model simplifies a system, using a model because it is easier to understand than the actual system, which is more complex (Giyarsih and Alfana, 2013; Haliki, 2019). Needs analysis, problem formulation, system identification, system modeling, model validation, and implementation are the stages of problem-solving using a dynamic system approach (Forrester, 1989; Sterman, 2002).

2.1 Needs Analysis

The dynamic model that is designed should be able to meet the needs of every stakeholder that can affect food security, whether it has a positive or negative effect. Therefore, it is necessary to identify the needs of each stakeholder who is involved and has an interest in the system. Based on a literature study and in-depth interviews, the influential stakeholders and their needs in food security and their needs are:

1. Land Ownership/Farmers
   a. High product selling price
   b. Facilities and infrastructure assistance
   c. Availability of water
2. Government
   a. Boost production rate
   b. Pushing the crop index
   c. Encouraging production quality
3. Society/Consumers
   a. Affordable rice price
   b. The quantity of rice is always sufficient
   c. Rice quality is good
4. Entrepreneur
   a. Cheap and strategic land
   b. Safety in business
   c. Availability of raw materials
5. Trading/Market System
   a. Maximum profit
   b. Stock continuity
   c. Strategic location
6. Financial/Banking Institutions
   a. Get customers
   b. Smooth debtor
   c. Technology advances

2.2 Problem Formulation

The increase in population increases the need for space, but space can no longer be increased. This causes the conversion of agricultural land to non-agricultural land, disrupting food security; if not addressed, it can lead to famine. The government has made various efforts, including the stipulation of the spatial plans (RTRW) and Law Number 41 of 2009 concerning the protection of sustainable food agricultural land. The regulation has not reduced the conversion of agricultural land. The dynamic system using a holistic approach is considered capable of studying the system as a whole to reduce the conversion rate of agricultural land. So far, the solution used does not examine all the phenomena, only examines per aspect.

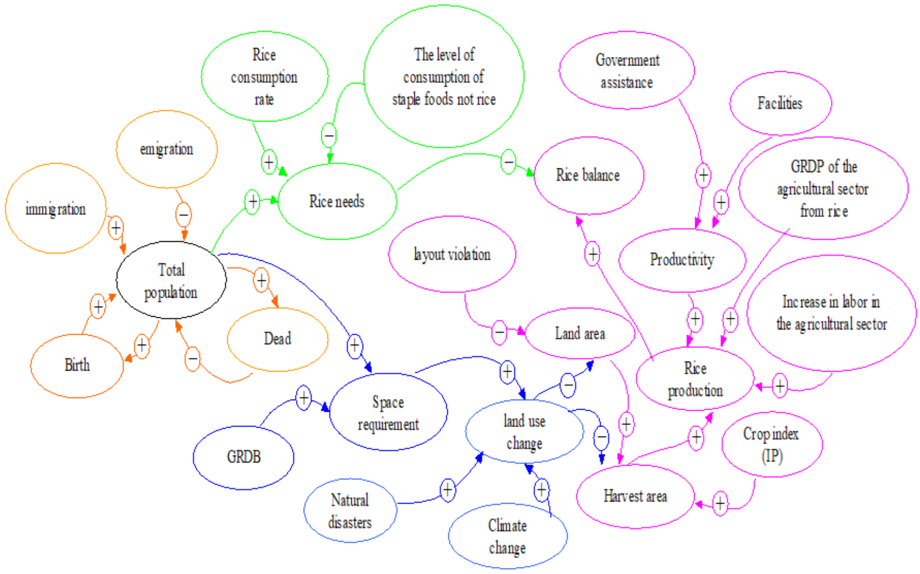

Figure 1. Causal Loop Diagram

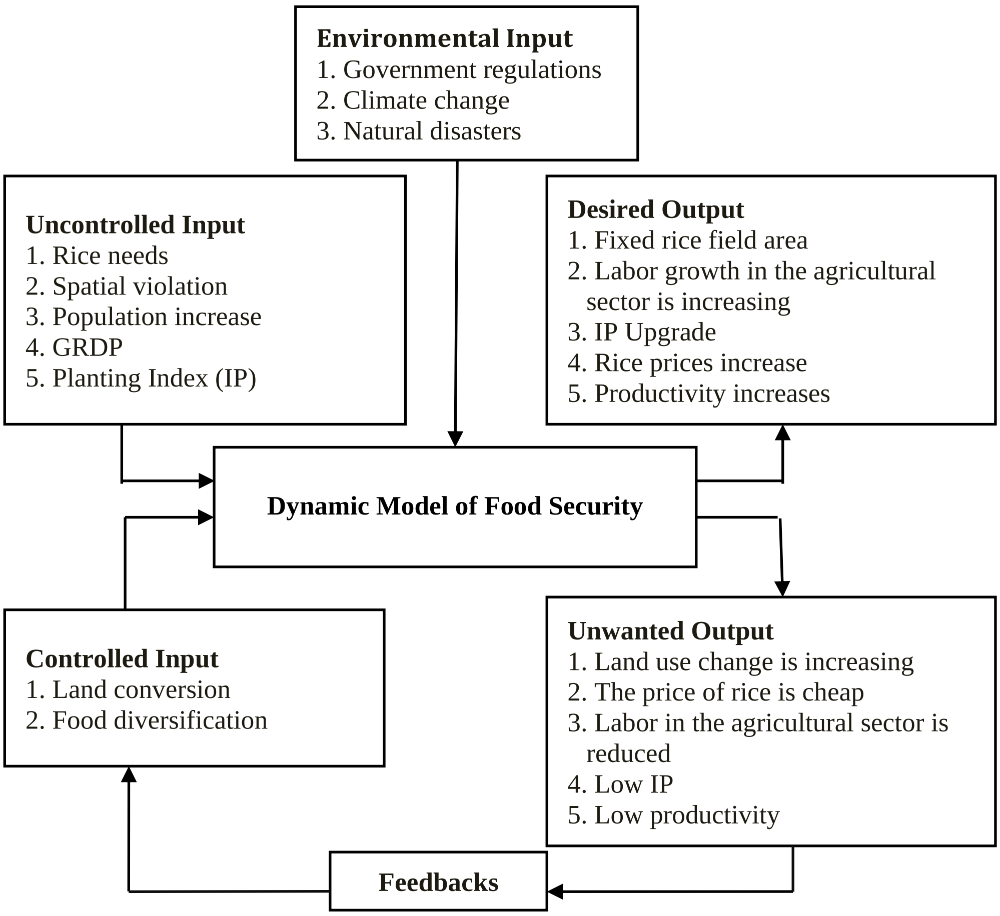

Figure 2. Input-Output Diagram

2.3 System Identification

System identification is a description of the system studied in the form of a diagram. The diagram used in the form of a causal loop diagram is based on a needs analysis, it can be seen in Figure 1, and the input-output diagram is presented in Figure 2.

2.4 Modeling

Inputs from the dynamic system include

spatial suitability analysis, geographic information systems, farmer behavior, and data from BPS and related agencies. The modeling uses inputs from dynamic systems, including spatial suitability analysis, geographic information systems, farmer behavior, and BPS data.

2.5 Model Validation

The model was validated by the MAPE (Mean Absolute Percentage Error) method. Model validation was carried out on population data.

3. Results and Discussion

3.1 Modeling

The dynamic system flow diagram is presented in Figure 3, a dynamic model structure that describes the relationships that occur between components in the system. Moreover, the initial data and the initial year of analysis used in this study is 2019. The system analysis was carried out for 11 years, from 2019 to 2030. The initial data and variables used in this study were population, rice demand, rice supply, land demand, paddy field area, production, and rice productivity.

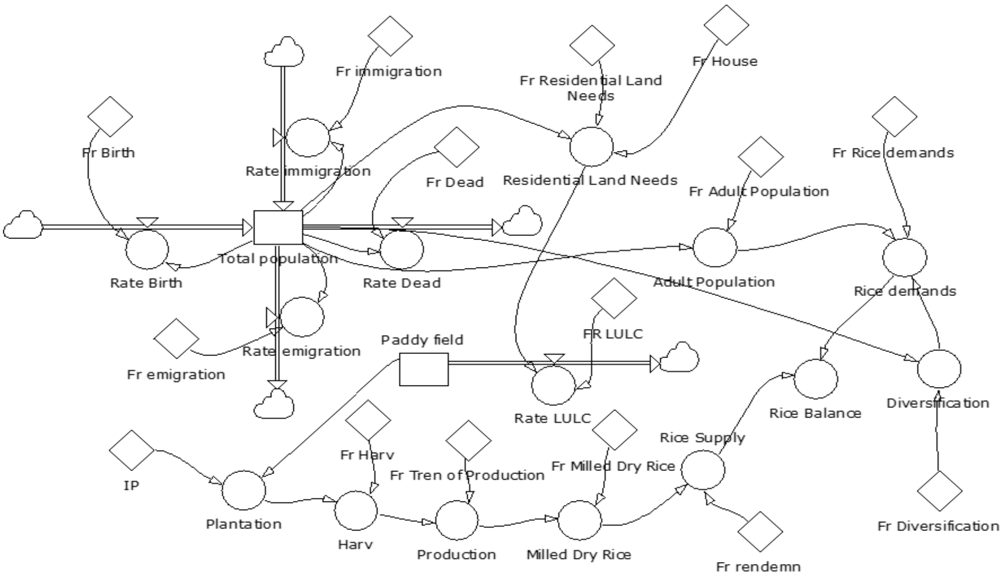

Figure 3 .**Flow Chart of The Modeling System**

3.2 Simulation

In Bantul Regency, Yogyakarta Special Region, population growth increases (Figure 4). In 2019 the population of Bantul Regency was 1,018,402 people, and in 2030 the end of the simulation reached 1,140,413 people. The population of Bantul Regency for 11 years from 2019–2030 experienced an additional population of 122,011 residents with an average population growth of 1.02% annually.

A conclusion section should be included and should indicate the paper's advantages, limitations, and possible applications. Although a conclusion may review the paper's main points, do not replicate the abstract as the conclusion. The conclusion should state the well-articulated outcome of the study.

The need for land for settlement is simulated based on the number of residents and the need for residential land per person. Residential land needs are calculated based on the SNI standard 03-1733-2004 concerning Urban Housing Environmental Planning procedures. The simulation result is presented in Figure 5. The need for land for settlement in Bantul Regency is already above 200 ha per year, with an average increase in demand for settlements reaching 2 ha per year. The high population causes the high number of land needs in Bantul Regency.

3.3 Model Validation

Validation of model performance is done by comparing the model output with actual data in the field/natural conditions. The model validation was carried out on the actual population data for 2010–2019. The model performance test using the Mean Absolute Percentage Error (MAPE) was carried out on the population data of Bantul Regency in 2010–2019; the results obtained were 1.378 percent. These results indicate a deviation of 1.4 percent between the model and the actual condition. MAPE validation results below 5 percent illustrate that the model built can describe actual conditions well. Furthermore, the result of the model validation can be seen in Table 1.

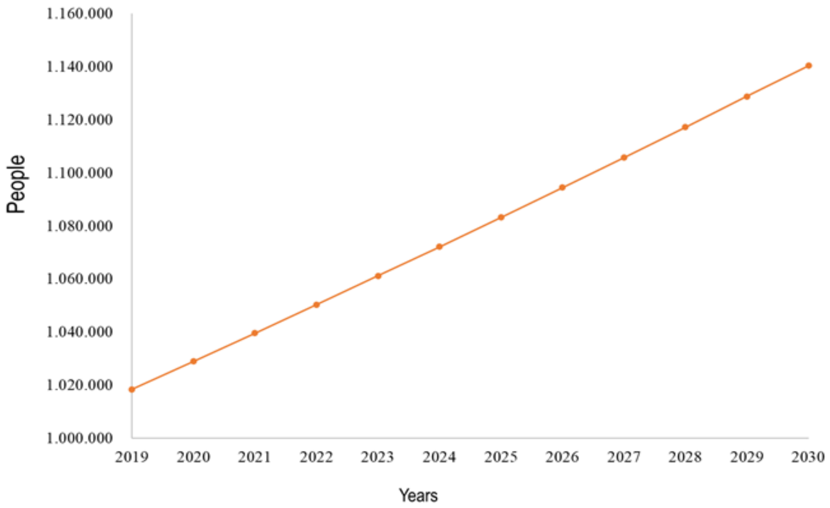

Figure 4. Simulation of The Population in Bantul Regency

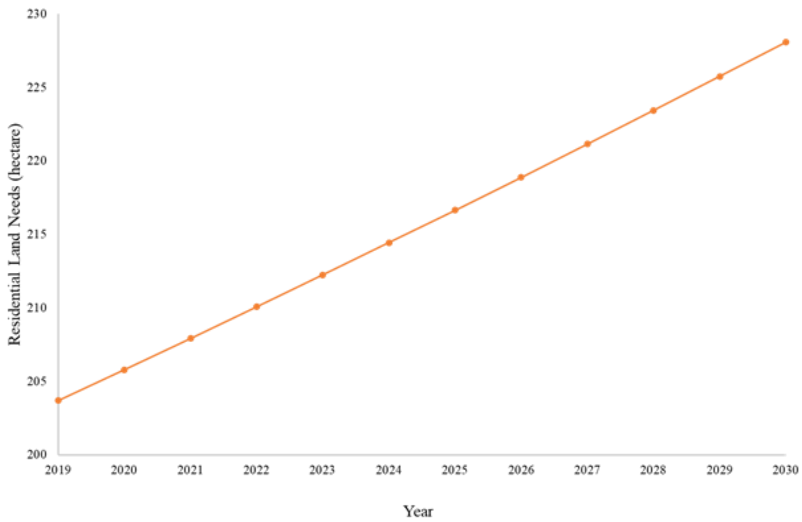

Figure 5. Residential Land Needs in Bantul Regency

Table 1. Absolute Validity Test Result Using the MAPE Method

Years	Actual	Predicted	Deviation	Error (%)
2010	911,503	911,503	0	0
2011	927,846	920,928	6,918	0.74
2012	941,414	930,450	10,964	1.16
2013	955,015	940,071	14,944	1.56
2014	968,632	949,792	18,840	1.94
2015	971,511	959,612	11,899	1.22
2016	983,527	969,535	13,992	1.42
2017	995,264	979,560	15,704	1.57
2018	1,006,692	989,688	17,004	1.68
2019	1,018,402	999,922	18,480	1.81
2020	1,030,928	1,010,261	20,667	2.00
			Average	1,37

3.4 Model Scenario

The model scenarios in this study are divided into three, namely business as usual (BAU), moderate, and optimistic. First is the BAU scenario without controlling the conversion of paddy fields. Second, they are pessimistic about controlling the transfer of functions to a maximum of 50% of the average annual conversion of paddy fields. Third, be optimistic with a maximum conversion of 50% of the average annual conversion of paddy fields and food diversification four times per month. The description of the rice balance scenario can be seen in Table 2.

By the topic in this study, it is a dynamic model of food independence to realize food sovereignty, not only to stop maintaining the existence of paddy fields. Food independence should first be achieved so that the ideals of food sovereignty can be realized. For Bantul Regency to maintain its food independence, it is necessary to control the conversion of paddy fields. This study scenarios policy based on controlled inputs to the model, namely the conversion of paddy fields and food diversification. Food sufficiency in this study is rice sufficiency for the people of the Bantul Regency. Based on the scenario results, if there is no control over the conversion of paddy fields, Bantul Regency will have a rice deficit in 2021. The rice deficit means that Bantul Regency cannot meet the rice needs of its population or does not have food independence in this study of rice commodities. In 2021, based on simulations, Bantul Regency could import 1,774 tons of rice from outside Bantul Regency to meet the rice needs of its population. The rice balance based on the three scenarios is presented in Figures 6, 7, and 8.

This scenario illustrates that Bantul Regency, with its rapid growth, impacts the agricultural sector. The optimistic scenario is the most feasible scenario to be implemented up to the policy stage by the Bantul Regency Government. The optimistic scenario is that the policy of transfer of function is controlled up to 50% of what it should be, and food diversification can maintain the excess rice balance until 2030. This scenario requires collective action from all levels of society in Bantul Regency and support from the Central Government. Socialization to all levels of society that the importance of maintaining paddy fields is essential to not to be diverted and promoting the food diversification movement.

Rice production depends on the area of paddy fields that are not changed in function and productivity. Based on the simulation results, it can be seen in Figure 9 that in 2100 Bantul Regency no longer produces rice because the paddy fields have been completely converted. However, if the Bantul Regency Government should make policies that can suppress the conversion of paddy fields to 50% of the rate it should be, rice production in 2030 will only be 101,096 tons per year.

In fact, the population of the Bantul Regency in 2020 was 954,706 people (Bantul Regency Website, 2023). The rice consumption needed is 82.2 kg/capita/year (Bappeda Jogja, 2023). Thus, the total need for rice in 2020 is 78,447 tonnes. Meanwhile, the total availability of rice in 2020 is 69,256 tons (BPS, 2022). Based on that, there was a rice shortage in 2020 of 9,221 tons.

Table 2. Scenario Model of Rice Balance with The Transfer of Function Control

No	Scenario	Policy	Rice supply (ton)	Rice demands (ton)	Balance (ton)
1	BAU	Without controlling the conversion of paddy fields	103,037.24	124,806.83	-21,769.59
2	Moderate	The conversion of paddy fields is a maximum of 50% of the average annual conversion of paddy fields	108,365.47	124,806.83	-16,441.36
3	Optimist	The conversion of paddy fields is a maximum of 50% of the average annual conversion of paddy fields and food diversification 4 times per month	113,160.87	107,700.63	5,460.24

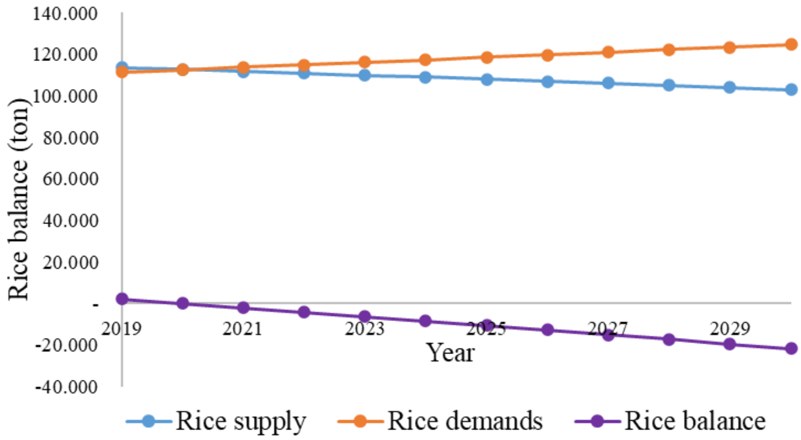

Figure 6. The Results of The Rice Balance Model Scenario BaU

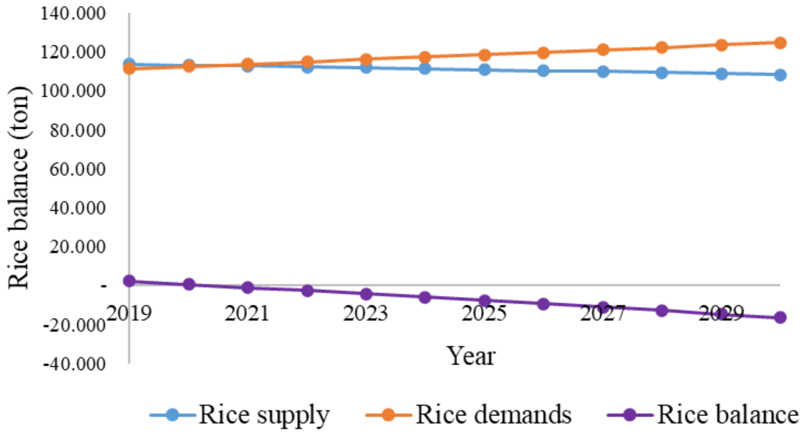

Figure 7 . The Results of The Rice Balance Model Scenario Moderate

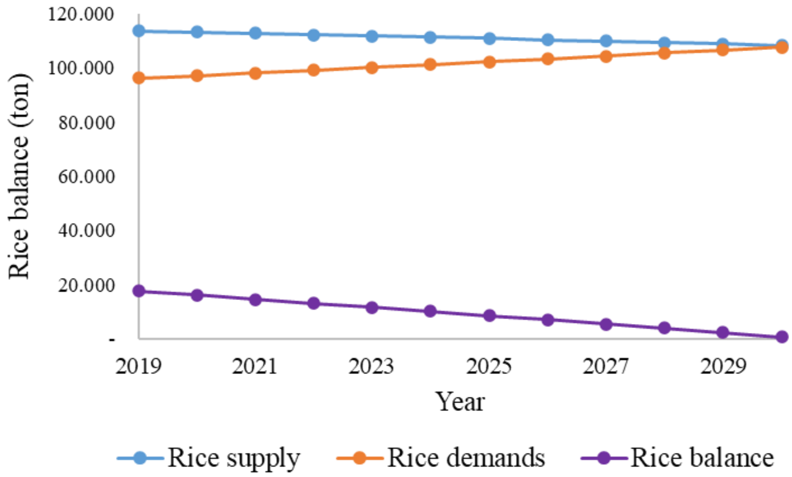

Figure 8 . The Results of the Rice Balance Model Scenario Optimistic

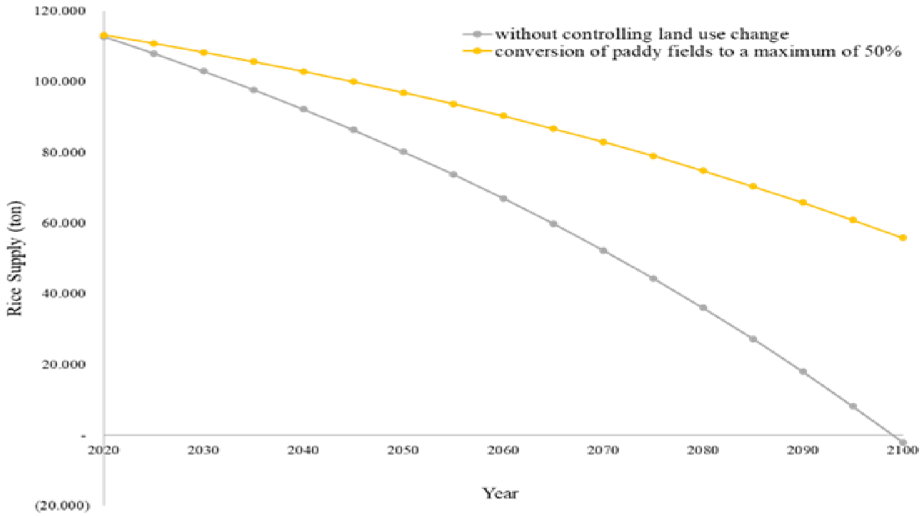

Figure 9 Simulation Results of Rice Supply Without Controlling the Conversion of Paddy Fields and Conversion of Paddy Fields to A Maximum of 50%

The conversion of paddy fields should be controlled to create food self-sufficiency. The factors that cause the conversion of paddy fields include the farmer's age, education level, land ownership, the distance between the paddy fields and the road, and the price of land. These five factors influence each other on the conversion rate of paddy fields. The distance of the paddy fields to the road dramatically affects the price of the paddy fields; the better the road access, the higher the price. Good road access makes paddy fields attractive to be converted into other businesses such as housing or shops. The majority of landowners who are not farmers tend to change the function of their paddy fields. When no one works or manages their fields, the land will experience a function change. The age and education of farmers influence rice field managers. If they are elderly, they have the opportunity to retire from work. Banguntapan sub-district, where most farmers are old, will not have farmers in the next few years. Sanden sub-district, which has low prices for paddy fields, is due to its distance from urban areas and difficult road access. The difficulty of road access makes Sanden District unattractive to be used as housing; besides that, Sanden District is far from the city.

It is necessary to set the right instrument so that the conversion of paddy fields can be controlled. Based on Law No. 41 in 2009 concerning LP2B, incentive and disincentive instruments have been formulated. Incentives are given to farmers who maintain their paddy fields, while disincentives are given to farmers who convert their paddy fields to non-agricultural uses. The Regional Government has made the LP2B Law a regional regulation of the Special Region of Yogyakarta, but the Bantul Regency LP2B has not been established. The Bantul Regency Government does not yet have regulations that can control the conversion of agricultural land. According to Daulay et al. (2016), difficulties in implementing LP2B are due to inadequate regulations, weak coordination between governments, and limited development funds. Local governments are advised to formulate the value of incentives received by farmers and tighten supervision over the implementation of the RTRW. This study scenario by applicable regulations that the conversion of paddy fields should be controlled and local food improvement/food diversification should be carried out.

Food diversification is the diversification of food sources to not rely on one food commodity. The majority of Indonesians still consume rice as their carbohydrate requirement. Based on data, rice consumption in Indonesia reaches 114 kg per capita per year, which is greater than the Asian average of 103 kg per capita per year (Oort et al., 2015) and (Rohman and Maharani, 2017). Wijayati et al. (2019) stated that 62.66% of the Indonesian population's carbohydrate needs are supplied from rice. The dominance of rice as a source of carbohydrate fulfillment for the Indonesian population makes the rice balance negative. The solution that should be developed is to reduce the population's dependence on rice.

Local food sources are an excellent solution to the population's dependence on rice. The government, both central and regional, has made regulations for local food consumption. Based on Law No. 18 in 2012 concerning food has been explained and mandated to develop local food. The Bantul Regency Government, through the Bantul Regent's Instruction No. 4 of 2012 concerning the Use of Local Food Raw Materials at Meetings/Meetings/Courses/Training/Field Work Visits, has tried to develop its local food.

So far, the promotion of policies on the use of local food in the Bantul Regency is still at the regional level (Aisyahi et al. 2020). The promotion of local food consumption needs to be extended to all levels of society in the Bantul Regency. Promotion can be done during agricultural extension activities, social media, and schools. Promotion of local food consumption should be carried out continuously until it becomes a culture, then rice consumption will decrease.

4. Conclusion

In the scenario without controlling land conversion in 2021, Bantul Regency's rice balance has been minus 1,925 tons. The scenario with the policy of controlling the conversion of paddy fields up to 50% of the rate of conversion of paddy fields. It can reduce the rice balance deficit in 2021; if the transfer of function is suppressed by 50% of the conversion rate of paddy fields, the rice balance will be minus 1,001 tons. The best scenario for sustainable agricultural land is to combine control over the conversion of paddy fields to 50% of the conversion rate of paddy fields and increase in food diversification, which will result in the 2030 rice balance reaching a surplus of 5,460.24 tons. The most feasible scenario to be implemented at the policy level is the scenario by combining control of paddy field conversion of 50% of the conversion rate of paddy fields and increasing food diversification.

The limitation of this study problem is the data on the conversion of paddy fields that are taken into account are irrigated and rainfed rice fields. In addition, the factors that are modeled in dynamic modeling are the only dominant factors. Further research is expected to periodically monitor the area of paddy fields using satellite imagery data in order to find out the existing ones and be able to make appropriate policies. Then, local governments are advised to promote the food diversification movement in order to reduce rice consumption.

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