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Food Crop Commodity Fulfilment Strategies Using a Dynamic System Approach

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A B S T R A C T

Teluk Bintuni Regency is one of the food-insecure areas in Indonesia. In 2013, the production of staple crops in Teluk Bintuni Regency was very low, making it unable to meet the food needs in the region. This study aims to formulate strategies for fulfilling food needs in Teluk Bintuni Regency through a dynamic system approach. In general, this research consists of four main stages, i.e. data inventory, dynamic model design, data analysis, and recommendation formulation. The research results show that there is a need to optimize the use of agricultural land that has been designated by the government for the cultivation of rice, corn, and soybean crops to meet food needs in Teluk Bintuni Regency. The land provided by the Teluk Bintuni Regency Government for the development of food crops will be able to meet the food needs in Teluk Bintuni Regency until 2050

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INTRODUCTION

Food security is one of the global and national issues. The government, through Law No. 18 of 2012 and the Sustainable Development Goals (SDGs) program, is committed to addressing food issues in Indonesia with the goal of achieving zero hunger by 2030 (National Food Agency, 2023b). The target is for 96.40% of the Indonesian population to have access to sufficient food throughout the year (Ministry of National Development Planning/National Development Planning Agency, 2021).

Teluk Bintuni Regency is one of the food-insecure areas in Indonesia. In 2023, the Food Security Index (IKP) in Teluk Bintuni Regency was only 40.88 (National Food Agency, 2023b), which places it as a region highly vulnerable to food insecurity (National Food Agency, 2023b). One of the factors contributing to the low food security in Teluk Bintuni Regency is the low availability of food supplies (National Food Agency, 2023b). According to data from the Central Statistics Agency (BPS), the production of several staple crops in Teluk Bintuni Regency is very low, including rice (86.70 tons) (BPS Teluk Bintuni Regency, 2024), corn (86 tons) (BPS Teluk Bintuni Regency, 2024), and soybeans (19.20 tons) (BPS Teluk Bintuni Regency, 2018). Therefore, various strategies are needed to meet the food requirements in Teluk Bintuni Regency.

The dynamic system is a simulation model widely used for analyzing the availability of food supplies and formulating strategies for food security. Arif Faisol et al. (2023) used the dynamic system to formulate strategies for fulfilling several staple crop commodities in Manokwari Regency. Furthermore, Arif Faisol et al. (2023b) conducted an analysis and projection of rice paddy land requirements in Manokwari Regency using a dynamic system to meet rice needs up to 2050. Sintiya (2023) used the dynamic system to analyze rice availability in Indonesia. Annisa (2022) used the dynamic system in analyzing the availability of land to increase food production. Somantri (2020) used the dynamic system to identify rice availability in Merauke. This research aims to analyze and project the commodity needs of staple crops in Teluk Bintuni Regency using the dynamic system and to formulate strategies to support food security in the region. The staple crops analyzed are rice, corn, and soybeans.

LITERATURE REVIEW

1. *Dynamic Systems*

Dynamic systems are qualitative description methods, understanding, and analysis of complex systems within the scope of processes, information, and organizational structures, facilitating quantitative modeling simulations and policy analysis of system structures and controls (Daalen & A. H. T, 2001). Dynamics is an analysis method where time is a crucial factor, encompassing understanding how a system can be maintained against external disturbances or tailored to the objectives of the system modeling to be developed (Coyle, 1996).

Dynamic systems for food security have been developed in developing countries, where a systems perspective illustrates the interconnections and interdependencies among factors to address management issues. Policymakers tend to view models considering the potential influences, trends, and behavioral habits of the policies to be decided (Giraldo et al., 2008). With the dynamic systems approach, forecasting activities become more accurate and informative than merely using statistical calculations. This approach also allows for short to medium-term forecasting (Lyneis, 2000).

There are five steps in creating a dynamic system model (Suryani et al., 2021):

- *Problem Articulation:* Defining the problem to be solved using the dynamic system model and identifying the related variables.
- *Dynamic Hypothesis*: Creating a Causal Loop Diagram to depict causal relationships among variables within the system. This diagram is then transformed into a Flow Diagram for simulation purposes.
- *Formulation:* Converting system elements and variables into equations, levels, rates, and auxiliaries, and estimating initial values and parameters.
- *Testing:* Comparing simulation outputs with real system outputs to validate the model, following verification and validation procedures.
- *Policy Formulation and Evaluation*: Using the developed model as a reference to formulate or evaluate policies related to the modeled system.

In its application, dynamic systems utilize various scenarios that can influence the organization's or company's operations in subsequent years. The outcomes of these scenarios can inform decisions and policies. With the numerous advantages of the dynamic systems approach, it is hoped that the decisions or policies issued will be optimal.

2. *Relevant Research*

Dynamic system modeling has also been used to support food self-sufficiency policies in Indonesia, such as for soybeans (Hasan et al., 2015; Oktyajati et al., 2018) and corn (Panikkai et al., 2017; Sarintang et al., 2021). Similarly, dynamic systems approaches have been applied in planning rice self-sufficiency policies to understand factors in line with phenomena (Alfa & Subagyo, 2018; Fristovana et al., 2020; Sulistyo et al., 2016) and rice availability in Bulungan Regency (Deslima Simanjuntak, 2023). Furthermore, dynamic systems have been used to support the National Beef Self-Sufficiency Program (Case Study: East Java) (Dhimas Dwijo Rahminto, 2018) and dynamic system

simulations of the potato supply chain in national food security efforts (M., M. Aminudin & Sari, 2014).

A region's food security is significantly influenced by the demand for and supply of food crops. If the demand exceeds supply, the region experiences a deficit and may need to import food. Conversely, if supply exceeds demand, the region has a surplus and can export food. The demand for food crops is affected by factors such as community consumption patterns, population size, and population growth. Supply is influenced by crop productivity, harvest area, and the Planting Index (IP) or planting frequency within a year. Projecting food crop needs is crucial for local governments to develop strategies to meet community food requirements, such as food imports, optimizing agricultural land, using superior varieties, and increasing the Planting Index. Food crop needs are influenced by population size, growth, and consumption patterns, while availability is affected by harvest area, productivity, planting index, and land availability for food crops.

3. Research Hypotheses

Hypotheses are preliminary assumptions that need to be tested for validity in research. Based on the above understanding, the hypotheses for this study are: 1. The demand for rice, corn, and soybean in Teluk Bintuni Regency from 2025 to 2050 will increase due to the rising population, 2. The demand for rice, corn, and soybean in Teluk Bintuni Regency from 2025 to 2050 can be met by increasing food crop production through optimal land utilization, enhancing the Planting Index, and using superior varieties.

METHODOLOGY

Tools

The tools used in this study include a computer and Vensim 10.0.0 educational version software.

Materials

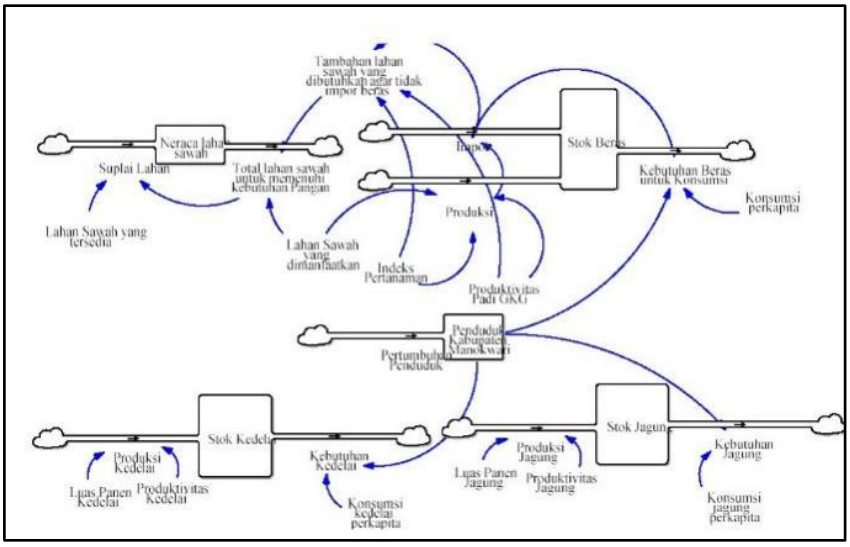
The materials used in this study include population data, per capita consumption of staple crop commodities, productivity of staple crops, available land area for food crops, and cropping patterns. Table 1 presents the data used in this study.

Table 1. Data and Sources Used in The Study

No	Data	Source
1	Population of Teluk Bintuni Regency in 2023	BPS Teluk Bintuni Regency
2	Population growth of Teluk Bintuni Regency	BPS Teluk Bintuni Regency
3	Productivity of rice, corn, and soybean	BPS Teluk Bintuni Regency
4	Available land area for food crops	Agriculture Office of Teluk Bintuni Regency
5	Cropping pattern	Survey
6	Per capita consumption of rice, corn, and soybean	National Food Agency

Research Procedure

In general, this study consists of four main stages: data inventory, dynamic model design, data analysis, and recommendation formulation. This stage aims to collect the data used in this study, which is obtained from relevant agencies and field observations (surveys). The data required for this study includes the population of Teluk Bintuni Regency in 2023, population growth of Teluk Bintuni Regency, productivity of several staple crops, available land area for food crops, per capita consumption of certain food crops, and cropping patterns. This stage aims to create a dynamic model based on the parameters that affect food needs and availability in Teluk Bintuni Regency. The dynamic model design to analyse and project the needs and availability of food commodities in Teluk Bintuni Regency is presented using a stock flow diagram, as shown in Picture 1.



Picture 1. Stock Flow Diagram for Analysing and Projecting the Availability and Needs of Food Crop Commodities in Teluk Bintuni Regency

Data Analysis

This stage aims to analyse the parameters that affect the needs and availability of food commodities. The parameters analysed include:

- **Population**

The population of Teluk Bintuni Regency is projected using the geometric method with the following equation (Central Statistics Agency, 2010):

$$Pn=Po(1+r)n\ldots (1)$$

Where, Pn=Projected population in year n (people), Po = Initial population in the base year (people), r = Average population growth rate (%), and n = Difference between the base year and the projected year.

- **Food Commodity Requirements**

The food requirement is calculated using the following equation (National Food Security Agency, 2019):

$$Fd=(Fd\ Percapita)/Pn \ldots\ldots\ldots\ldots (2),$$

Where Fd=Food requirement (kg), Fd per capita = Per capita food requirement (kg/person), and Pn= Projected population in the year (people).

- **Food Commodity Production**

The production of food crop commodities is calculated using the following equation:

$$P=A\times p \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: P=Food production (kg), A=Harvested area (ha), and p = Productivity (kg/ha)

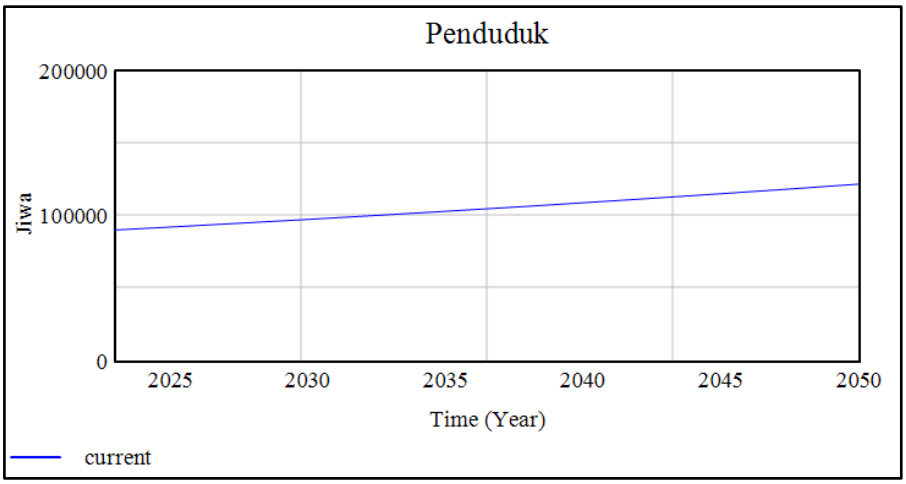
- **Formulation of Recommendations**

This stage aims to provide recommendations for meeting the food needs in Teluk Bintuni Regency, both through intensification and extensification approaches.

RESULTS AND DISCUSSION

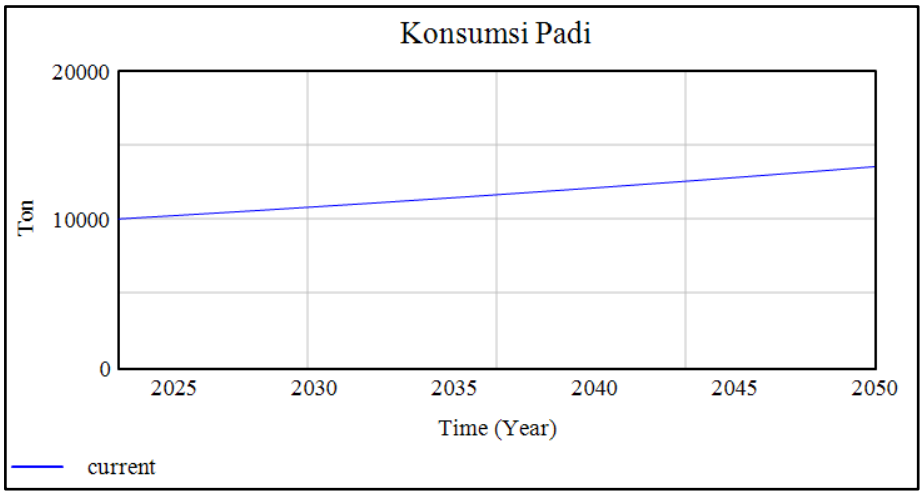
Based on data from the National Food Agency, rice consumption in Teluk Bintuni Regency in 2023 was 74.30 kg per capita per year (National Food Agency, 2023a), or 6,694.50 tons, corn consumption was 0.5 kg per capita per year (National Food Agency, 2023a), or 45.05 tons, and soybean consumption was 5.3 kg per capita per year (National Food Agency, 2023a), or 477.54 tons. Meanwhile, rice production in Teluk Bintuni Regency in 2023 was 86.70 tons, corn was 86 tons, and soybean was 0 tons (no soybean production) (BPS Teluk Bintuni Regency, 2024). Therefore, in 2023, Teluk Bintuni Regency experienced a corn surplus, while rice and soybeans experienced a deficit.

In 2023, the population of Teluk Bintuni Regency was 90,101 people, with a growth rate of 1.12% (BPS Teluk Bintuni Regency, 2024). As a result, the population of Teluk Bintuni Regency is projected to reach 97,407 people in 2030, 108,883 people in 2040, and 121,711 people in 2050. The population projection of Teluk Bintuni Regency from 2024 to 2050 is presented in Picture 2.



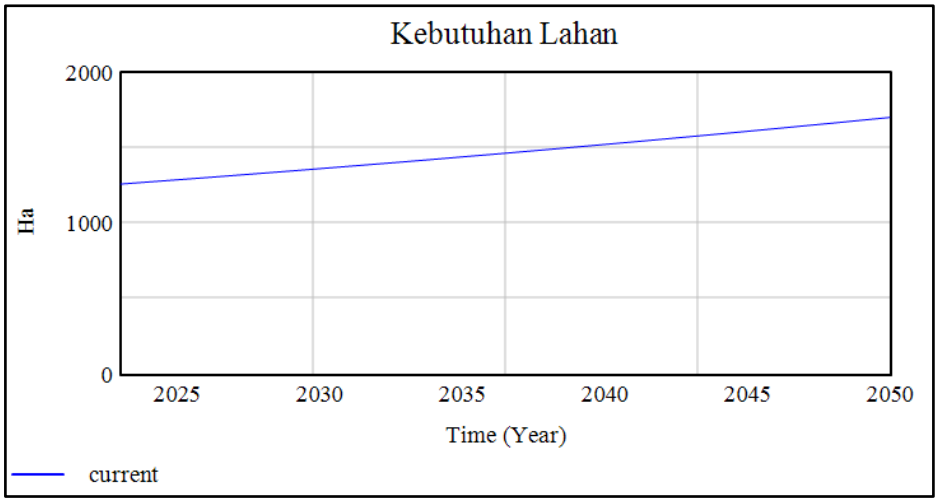
Picture 2. Population Projection of Teluk Bintuni Regency

In 2023, rice consumption in Teluk Bintuni Regency was 6,694.50 tons. When converted to milled rice (GKG) at 66.70% (Central Statistics Agency, 2018), the total rice requirement in Teluk Bintuni Regency for 2023 is 10,036.74 tons of GKG. Therefore, in 2023, Teluk Bintuni Regency experienced a rice deficit of 9,950.04 tons of GKG. In 2025, the rice requirement in Teluk Bintuni Regency is projected to reach 10,262.80 tons of GKG, in 2030 it will be 10,850.50 tons of GKG, in 2040 it will be 12,128.90 tons of GKG, and in 2050 it will be 13,407.70 tons of GKG. The rice requirement projection for Teluk Bintuni Regency from 2024 to 2050 is presented in Picture 3.



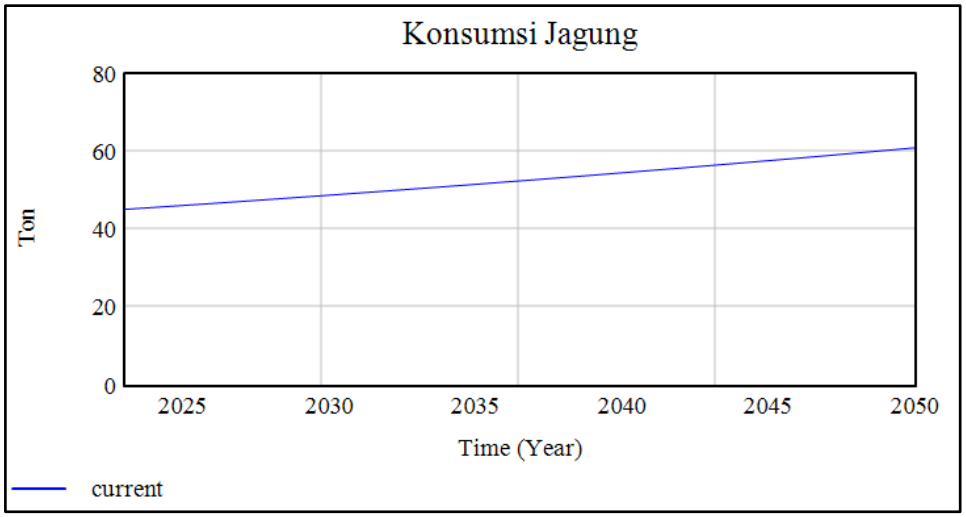
Picture 3. Projection of Rice Requirements in Teluk Bintuni Regency

In 2023, the harvested area for rice cultivation in Teluk Bintuni Regency was only [X] ha (BPS Teluk Bintuni Regency, 2024), while the available land for the development of food crops is approximately 1,820 ha (Agriculture Office of Teluk Bintuni Regency, 2023). The productivity of rice crops in Teluk Bintuni Regency in 2020 was 3.988 tons/ha (BPS Teluk Bintuni Regency, 2024), with two planting seasons per year. In 2025, the paddy land requirement in Teluk Bintuni Regency is projected to reach 1,286.71 ha, in 2030 it will be 1,360.40 ha, in 2040 it will be 1,520.67 ha, and in 2050 it will be 1,699.84 ha. Therefore, if the available land is optimized, Teluk Bintuni Regency will not need to import rice to meet its food needs until 2050. The projection of paddy land requirements in Teluk Bintuni Regency from 2024 to 2050, based on dynamic system analysis, is presented in Picture 4.



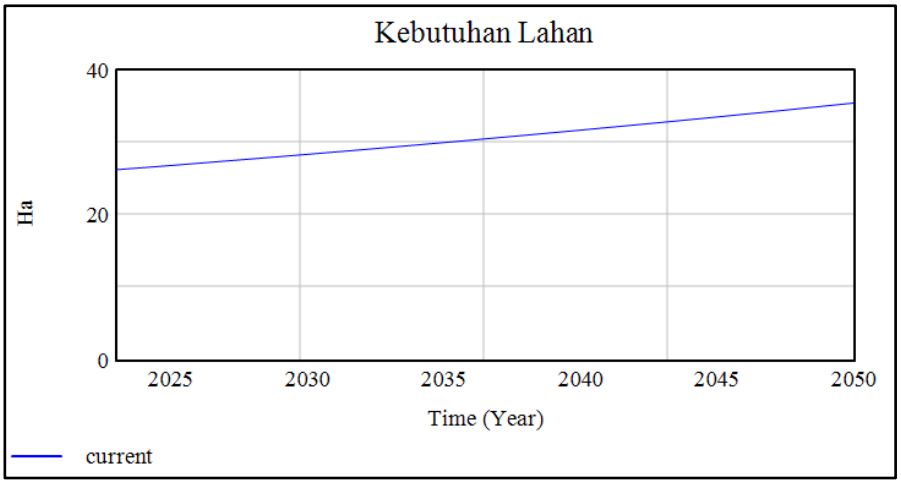
Picture 4. Projection of Paddy Land Requirements in Teluk Bintuni Regency

In 2023, corn consumption in Teluk Bintuni Regency was 45.05 tons, while corn production reached 86 tons (BPS Teluk Bintuni Regency, 2024) with a harvested area of 43 ha (BPS Teluk Bintuni Regency, 2024). Therefore, in 2023, Teluk Bintuni Regency experienced a corn surplus of 40.95 tons. In 2025, the corn requirement in Teluk Bintuni Regency is projected to reach 46.07 tons, in 2030 it will be 48.70 tons, in 2040 it will be 54.44 tons, and in 2050 it will be 60.18 tons. The projection of corn requirements in Teluk Bintuni Regency from 2024 to 2050 is presented in Picture 5.



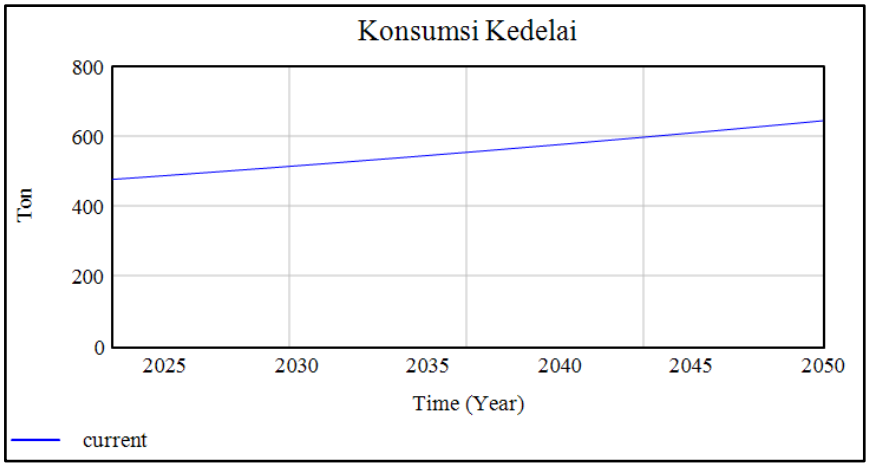
Picture 5. Projection of Corn Requirements in Teluk Bintuni Regency

The productivity of corn crops in Teluk Bintuni Regency in 2022 was 1.72 tons/ha (BPS Teluk Bintuni Regency, 2024), with one planting season per year. In 2025, the land requirement for corn cultivation in Teluk Bintuni Regency is projected to be 26.78 ha, in 2030 it will be 28.32 ha, in 2040 it will be 31.65 ha, and in 2050 it will be 35.38 ha. Therefore, there is no need to increase the harvested area for corn crops to meet the corn requirements in Teluk Bintuni Regency. The projection of paddy land requirements in Teluk Bintuni Regency from 2024 to 2050, based on dynamic system analysis, is presented in Picture 6.



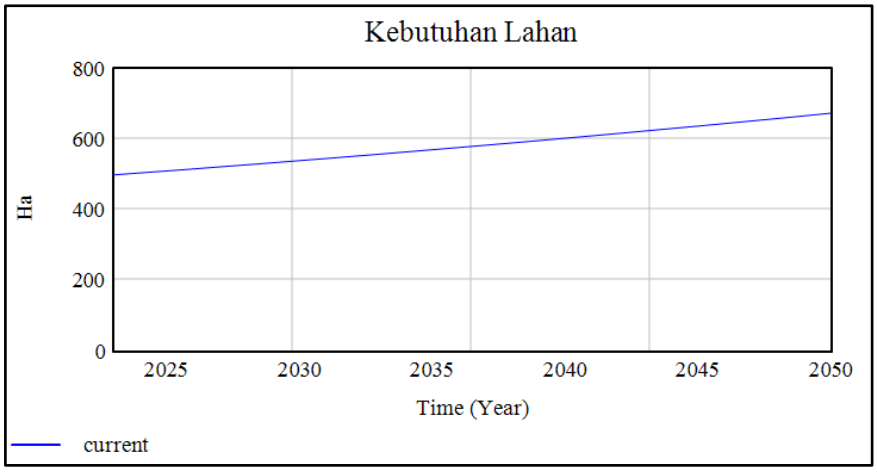
Picture 6. Projection of Corn Land Requirements in Teluk Bintuni Regency

In 2023, soybean consumption in Teluk Bintuni Regency was 477.54 tons, and there was no soybean production in 2023 (BPS Teluk Bintuni Regency, 2024). Therefore, in 2023, Teluk Bintuni Regency experienced a soybean deficit of 477.54 tons. In 2025, the soybean requirement in Teluk Bintuni Regency is projected to reach 488.29 tons, in 2030 it will be 516.26 tons, in 2040 it will be 577.08 tons, and in 2050 it will be 645.07 tons. The projection of soybean requirements in Teluk Bintuni Regency from 2024 to 2050 is presented in Picture 7.



Picture 7. Projection of Soybean Requirements in Teluk Bintuni Regency

The productivity of corn crops in Teluk Bintuni Regency is 0.96 tons/ha (BPS Teluk Bintuni Regency, 2018), with one planting season per year. In 2025, the land requirement for soybean cultivation in Teluk Bintuni Regency is projected to be 508.64 ha, in 2030 it will be 537.77 ha, in 2040 it will be 601.12 ha, and in 2050 it will be 671.95 ha. Therefore, there is no need to increase the harvested area for corn crops to meet the corn requirements in Teluk Bintuni Regency. The projection of paddy land requirements in Teluk Bintuni Regency from 2024 to 2050, based on dynamic system analysis, is presented in Picture 8.



Picture 8. Projection of Soybean Land Requirements in Teluk Bintuni Regency

CONCLUSIONS AND RECOMMENDATIONS

There is a need to optimize the use of agricultural land that has been designated by the government for the cultivation of rice, corn, and soybean crops to meet food needs in Teluk Bintuni Regency. The land provided by the Teluk Bintuni Regency Government for the development of food crops will be able to meet the food needs in Teluk Bintuni Regency until 2050.

FURTHER STUDY

This research still has limitations, so further research is needed related to the topic of Food Crop Commodity Fulfillment Strategies Using a Dynamic System Approach in order to perfect this research and increase insight for readers.

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