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AVAILABILITY OF CORN COMMODITY IN ACHIEVING FOOD SELF-SUFFICIENCY: DYNAMIC SYSTEMS MODEL APPROACH

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Abstract

The rice, corn, and soybean Special Efforts Program (UPSUS PAJALE) is a government program administered by the Ministry of Agriculture that aims to achieve long-term self-sufficiency. Corn is a strategic commodity due to its use as feed, food, and industrial raw material. Corn demand is rising in tandem with population growth, so it must be maintained to avoid scarcity. Dynamic systems can forecast demand and availability and forecast future models. Secondary data was used in the data collection method from 2012 to 2021. This study examines the factors that have a direct impact on corn balance and creates scenarios using the system dynamic model. Powersim Studio 10 software is used in system dynamic modeling to simulate current conditions and create several alternative scenarios in an effort to increase corn production, while the MAPE (Mean Absolute Percentage Error) method is used to check model validation. The results of the study show that based on actual conditions (Scenario 0), self-sufficiency will never be achieved. Self-sufficiency will be successful in 2021 if the productivity increase scenario is implemented (Scenario 1) and the use of dryer technology (Scenario 2).

Keywords: Self-Sufficiency, Balance-Sheet, Corn, Modeling

INTRODUCTION

Indonesia is experiencing positive population growth, which is increasing opportunities to meet food needs. There will be problems in the future if the need for food is not accompanied by an increase in food production. The increase in population is directly proportional to the increase in food demand (Sinaga et al., 2022)(Paly, 2019). Food needs cannot be met due to limited food production and distribution capacity (Vanany et al., 2021). Because of these constraints, there is food insecurity between national needs and fulfillment (Nasikh, 2018)(Murniati & Mutolib, 2020). Due to limited national production capacity, the government established the Special Efforts Program for Rice, Corn, and Soybeans (UPSUS PAJALE) to increase rice, corn, and soybean food commodity production in an effort to achieve long-term self-sufficiency.

Corn is a strategic food crop because it, like rice, can be used as a source of carbohydrates. By 76.3%, the demand for corn is dominated by its use as the primary raw material for the animal feed industry and poultry feed (Woyengo et al., 2017)(Johnson et al., 2020). During the 2015-2018 period, the average corn export volume was only 58,210 tons, while the import volume was significantly higher, at 1,231,098 tons (Kementerian Perdagangan, 2020). The high value of imports in comparison to the value of exports results in an always negative balance (Yusron et al., 2018)(Adamtey et al., 2016) . A negative balance resulted in a deficit in the growth of export-import corn in Indonesia. The high value of corn imports demonstrates the country's

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increasing reliance on imported corn, so efforts to increase domestic corn production are required. Self-sufficiency can be attained if production is increased (Hamilton-Hart, 2019).

The mapping of corn production centers in Indonesia for 2012-2021 revealed that East Java Province contributed the most to national corn production (30.93%), followed by Central Java (15.89%) (Badan Pusat Statistik 2021). The total contribution of corn production on the island of Java reached 52.34% of total national production. The total contribution of provinces other than Java Island is 37.22%, spread across seven provinces. The contribution of national production to provinces other than the central provinces is 10.53%. (Kementerian Pertanian, 2020);(Respatiwulan et al., 2018).

Central Java Province is ranked second in the country's top ten maize center provinces. This demonstrates that Central Java Province's corn production currently has a significant impact on national corn production. Corn production in Central Java Province grows year after year, but the demand for corn grows as well, particularly as animal feed (Ekowati et al., 2018).

Experts use a variety of methods to determine strategic policy directions for potential corn crops (Sitko et al., 2017) (Groenewald & Niehof, 2015). However, the corn production constraints have not been adequately addressed until now. It is necessary to develop scenarios that can be used to determine the steps that policymakers can take to manage food self-sufficiency (Oktyajati et al., 2018).

Several researchers have conducted research on the dynamic system model of corn, but the variable needs for corn commodities are still general. The novelty in the development of the dynamic system model design for corn commodities stems from a supply-demand gap, which has a direct impact on the balance of corn commodities. This study aims to examine the factors that have a direct impact on corn balance and to develop a corn availability policy in Central Java in order to achieve a corn self-sufficiency program using system dynamic modeling.

RESEARCH METHOD

Secondary data was used in this study. Secondary data is information gleaned from reports, agricultural statistics books, and other secondary sources about the supply-demand for corn in Central Java from 2012 to 2022. Powersim Studio 10 software is used for model engineering, and Microsoft Office software is used for data processing.

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Figure 1. Research Methodology for Central Java Corn Balance Modeling

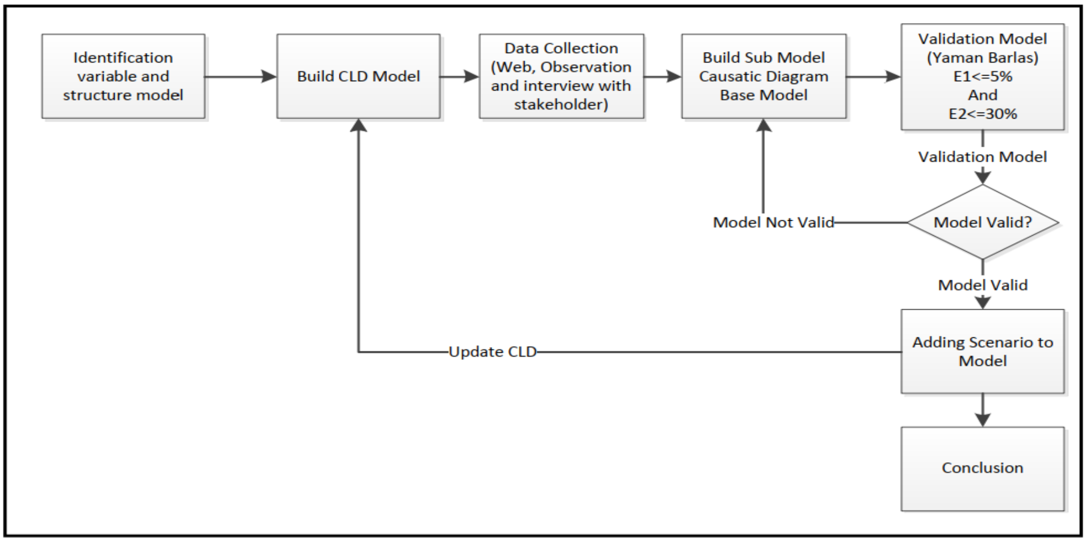

Table 1: Types and Sources of Research Data

Data Type	Data Source
Central Java corn production (2012-2021)	Badan Pusat Statistik
Land area harvested for corn in Central Java (2012-2021)	Badan Pusat Statistik
Corn productivity data (2012-2021)	Badan Pusat Statistik
Population in Central Java (2012-2021)	Badan Pusat Statistik
Per capita consumption of corn in Central Java (2012-2021)	Dinas Pertanian
Poultry Population in Central Java (2012-2021)	Kementrian Pertanian
Manufactured Feed Production in Central Java (2012-2021)	Kementrian Pertanian
Maize Food Production in Central Java (2012-2021)	Dinas Perdagangan

Dynamic System Model

Previous studies on food self-sufficiency used the system dynamic method with commodities such as corn, rice, sugar, and rice as references, including (Oktyajati et al., 2018)(Aprillya et al., 2019)(Indriana et al., 2020)(Putra et al., 2018)(Khodeir & Abdelsalam, 2016). During the analysis phase, the general system approach includes problem formulation, dynamic hypothesis formulation, model formulation, testing, and scenario preparation (Tastra et al., 2019)(Rahmah et al., 2017) dan (Wening Kusuma & Rachbini, 2019).

The use of a dynamic system methodology emphasizes increasing understanding of the behavior that results from the system's policy structure (Iswanto, 2012). This understanding is critical for developing effective policies (Sitompul, 2009).

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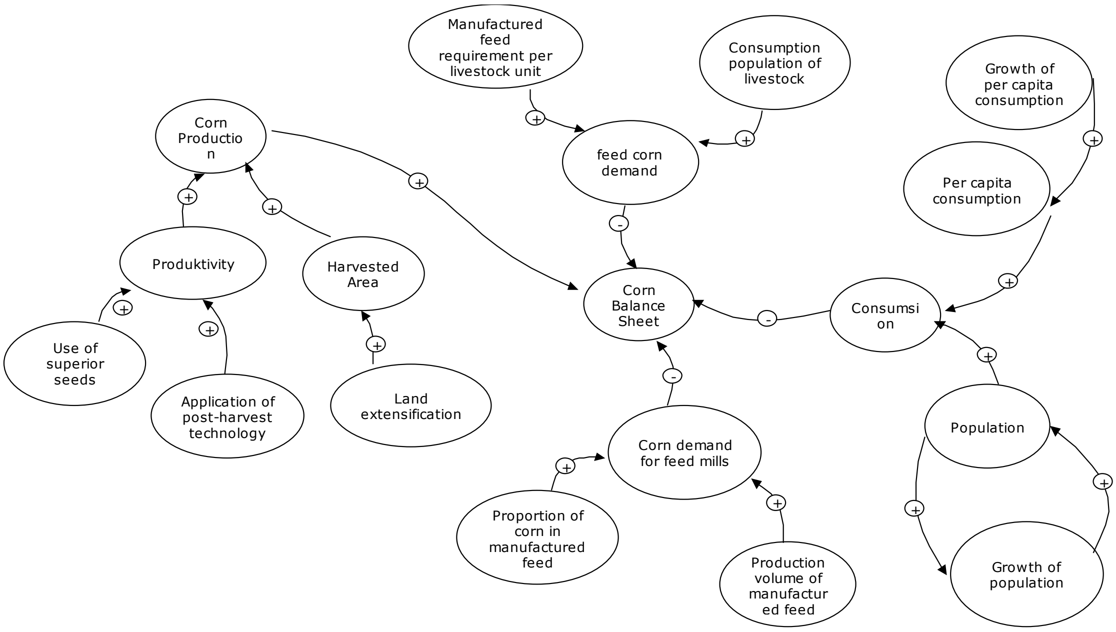
Figure 2. Causal Loop Diagram of Maize Availability in Central Java



Understanding of the model to be created, followed by its arrangement into a causal loop diagram. The causal loop diagram is divided into two subsystems: the corn production subsystem and the corn demand subsystem. Corn demand is divided into three subsystems: poultry feed, raw materials for animal feed companies, and food ingredients. Increased demand can lead to intensification and extensification of production (Wening Kusuma & Rachbini, 2019) dan (Shi et al., 2016). In this model, increasing production is an intensification effort that involves using drying machine technology to increase yield values (Khanali et al., 2018) and superior hybrid corn seeds to increase crop yields (Wych, 2015) dan (Meki et al., 2020).

The corn production subsystem is made up of land area and productivity, both of which have a significant and positive effect on corn production under the same conditions (Wibowo et al., 2019). Each variable's function in optimizing and increasing the corn balance can be improved by increasing it. It is, however, distinct from the requirements of the corn subsystem. Despite the fact that the number of needs is growing, this will have an impact on the corn balance.

Verification and Validation

The consistency of the model structure is examined with descriptive knowledge of the systems involved in the modeling process during structural verification. In order to validate the developed model, various model behavior tests can be used. The recommended statistical method was used for the testing (Sutraprawata, 2006). Sitompul (2009) used visual and statistical validation to validate the model developed using system dynamics. The MAPE (Mean Absolute Percentage Error) test is one of the model validation methods. MAPE is one percentage error measure. This test can be used to determine whether estimated data results are compatible with actual data.

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$$MAPE = \frac{1}{n}\sum \frac{X_m - X_d}{X_d} x100\% \qquad \text{(1)}$$

Description:

Xm = Simulated data

Xd = Actual data

n = Number of data

If the MAPE value of a model is < 5%, it is classified as very precise in describing the actual conditions. MAPE values between 5% and 10% are quite appropriate for describing actual conditions, while MAPE values > 10% are not appropriate for describing actual conditions (Teh, 2006). Model validation ensures that the model built can accurately represent actual conditions. When the deviation is less than 10%, the model is declared valid.

Simulation

Table 2: Modeling Policy Scenarios

Scenario	Scenario Formation	Information
0	Actual conditions	All parameters used are the same as the current conditions.
1	Increasing production through increasing productivity by using superior seeds	Grobogan Regency, as a pilot set as a corn barn for Central Java Province, has implemented an expansion of the harvested area by cultivating high-yielding hybrid corn seeds with the potential to produce a productivity of 14.3 tonnes/ha. 85% of farmers use hybrid seeds. The yield potential will be greater if applied to Central Java.
2	The combination of the use of superior seeds and drying machine technology	Access to technology, particularly drying machines, remains limited because many farmers continue to use traditional drying methods. The use of a drying machine is expected to increase corn yield.

The simulation is only run until 2031 to see if the goal of corn self-sufficiency can be met while adhering to the zero-import agenda. Somantri (2007) and Axella (2012) argue that scenarios in the form of structural policies are designed to assess an object's ability and reliability to achieve the ultimate goal. The valid model is then simulated, with 2012 as the starting point for the simulation (t=0), and the policy scenario implemented beginning in 2021. This is due to the fact that the new self-sufficiency policy was implemented from 2017 to 2021.

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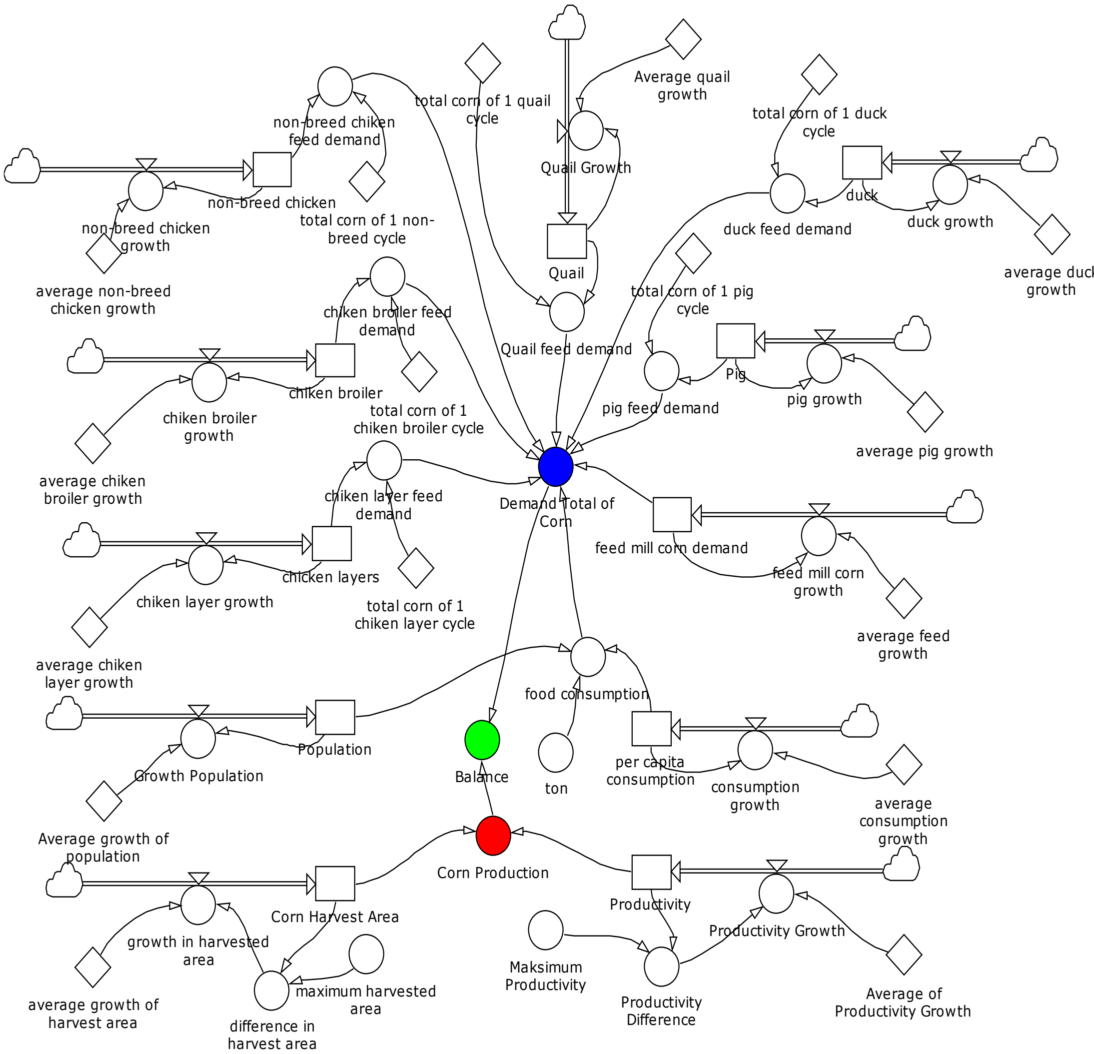
RESULTS AND DISCUSSION

Figure 3. Stock Flow Diagram of Corn Availability in Central Java



The corn supply system modeling in Central Java is divided into two sub-systems, as seen in the Stock Flow Diagram: (a) Central Java corn production sub-system and (b) Central Java corn demand sub-system. The two subsystems will then be divided into six models: harvested area; corn production; resident; the need for corn for poultry livestock; the need for corn for animal feed factories; and the need for food ingredients. Model validation was performed on data from 2012 to 2021, as evidenced by the results of MAPE calculations on harvested area and productivity of randomly selected corn in Tables 3 and 4. The MAPE value in terms of harvested area level performance is 3.4%, indicating that the model is very appropriate, and the MAPE productivity level is 8.25%, indicating that the model is correct..

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Table 3. MAPE Level of Corn Harvested Area

Year	Actual Production (Ton)	Simulation Production (Ton)	MAPE
2012	553.372	553.372	0
2013	532.061	553.654	4,058369
2014	538.102	553.934	2,942193
2015	542.804	554.214	2,102048
2016	563.012	554.492	1,513289
2017	588.812	554.768	5,781812
2018	568.631	555.043	2,389599
2019	566.767	555.317	2,020231
2020	611.082	555.590	9,080942
2021	582.432	555.861	4,562078
MAPE (%)			**3,445056**

Table 4. MAPE Level of Corn Productivity

Year	Actual Production (Ton)	Simulation Production (Ton)	MAPE
2012	5,497	5,40	1,764599
2013	5,509	5,41	1,797059
2014	5,671	5,41	4,602363
2015	5,918	5,42	8,415005
2016	6,003	5,43	9,545227
2017	6,131	5,43	11,4337
2018	6,059	5,44	10,21621
2019	6,118	5,44	11,08205
2020	6,237	5,45	12,61825
2021	6,141	5,46	11,0894
MAPE (%)			**8,256386**

Maximum Productivity Value Limitation

The conditions of the scenarios prepared determine the maximum value or goal seeking in the productivity variable. The maximum productivity value for Scenario 0 is calculated using the highest corn harvested area in 2020, which is 6.237 tons/ha. Meanwhile, according to the Planting Period 1 pattern, the main harvest occurs at the end of February, coinciding with the rainy season, corn is susceptible to pest attack, and it has a high moisture content ranging from 25-35%. As a result, the harvested area accounts for only 72.34% of the total(Ruminta et al., 2018) dan (Ariningsih et al., 2021). Because of harvest losses based on seed yields, the maximum potential harvested area of superior seeds arranged in scenario 1 ranges from 14.3 tons/ha to 10.34 tons/ha. The productivity value for Scenario 2 is based on the use of technology

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to reduce the water content to 18%, which will increase yield by up to 80% (Huffman et al., 2018). The maximum productivity value of scenario 2 is higher, at 11.44 tons/ha based on shell yield. Figure 4 depicts the maximum productivity value for each of the three scenarios.

Figure 4. Maximum productivity values for scenario 0, 1, and 2

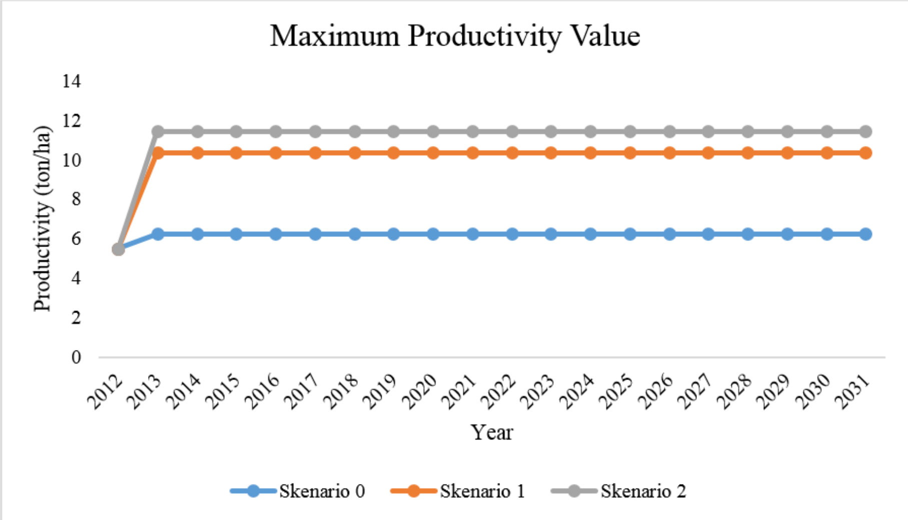
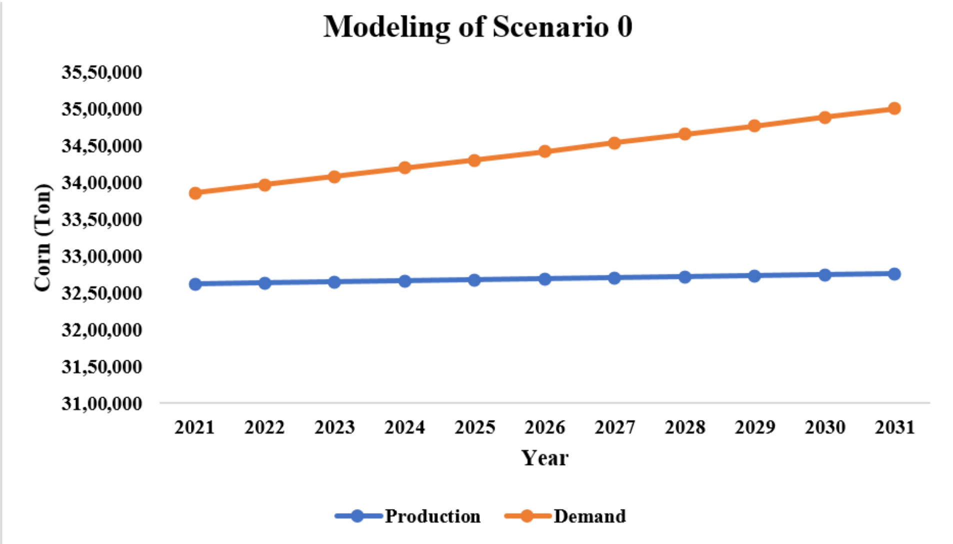


Figure 5. Growth of Corn Production and Demand in Central Java Scenario 0



Scenario 0 (Actual Condition)

Scenario 0 is a simulation scenario in which all parameter values are the same as the actual conditions listed in Tables 3 and 4. Scenario 0 serves as a control scenario for the development of the next scenario. The simulation results show that corn production will continue to fall short of demand until 2031. Due to insufficient productivity, self-sufficiency was not attained in

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2031. In 2020, the average productivity is only 5.6 tons/ha, and the highest productivity is only 6.24 tons/ha (Table 4). Figure 5 depicts a simulation of production and needs in Scenario 0

Figure 5 shows the annual increase in total corn production behavior. Although total production rises year after year, total demand for corn rises as well. Throughout the year, total production remains lower than total demand. According to Table 5, the balance in Scenario 0 never reaches a surplus.

Table 5. Simulation result data of corn Balance Sheet in scenario 0

Year	Corn Production (Ton)	Total Corn Demand (Ton)	Balance Sheet (Ton)
2021	3.261.619	3.385.229	-123.610
2022	3.263.115	3.396.404	-133.289
2023	3.264.604	3.407.648	-143.044
2024	3.266.089	3.418.961	-152.872
2025	3.267.568	3.441.800	-174.232
2026	3.269.042	3.453.326	-184.284
2027	3.270.510	3.453.326	-182.816
2028	3.271.973	3.464.924	-192.951
2029	3.273.430	3.476.595	-203.165
2030	3.274.882	3.488.339	-213.457
2031	3.276.329	3.500.157	-223.828

Scenario 1 (Increased Production through Increased Productivity)

Scenario 1 simulation attempts to increase production by increasing productivity by switching from non-rivaled corn seeds to superior hybrid corn seeds. Non-improved corn seed varieties have an average yield potential of 7.7 tons/ha, while superior hybrid corn seed varieties have an average yield potential of 12.27 tons/ha.

The scenario simulation 1 shown in Figure 6 with the substitution of high-yielding hybrid corn shows that Central Java Province will be able to meet the province's needs in 2021. As a result, the contribution to national corn production can be increased. Table 6 shows that corn self-sufficiency can be achieved in 2021, with a corn balance surplus of 109,363 tons predicted.

The farming analysis of non-improved corn seeds will be compared to superior hybrid corn seeds of Cap Panah Merah and BISI-2 varieties in scenario 1. The two varieties were chosen due to their similar harvesting ages and resistance to downy mildew disease. According to the findings of the farming analysis, the R/C ratio for high-yielding hybrid corn is 2.93, while non-improved corn only reaches 1.71. These figures imply that for every Rp 1 spent on farming, farmers will receive an additional Rp 2.93 if they plant high-yielding hybrid seeds. Superior corn seeds produce greater economic benefits than composite corn seeds (Sulistyono et al., 2018) dan (Apriani et al., 2017).

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Figure 6. Growth of corn production and demand in Central Java under scenario 1

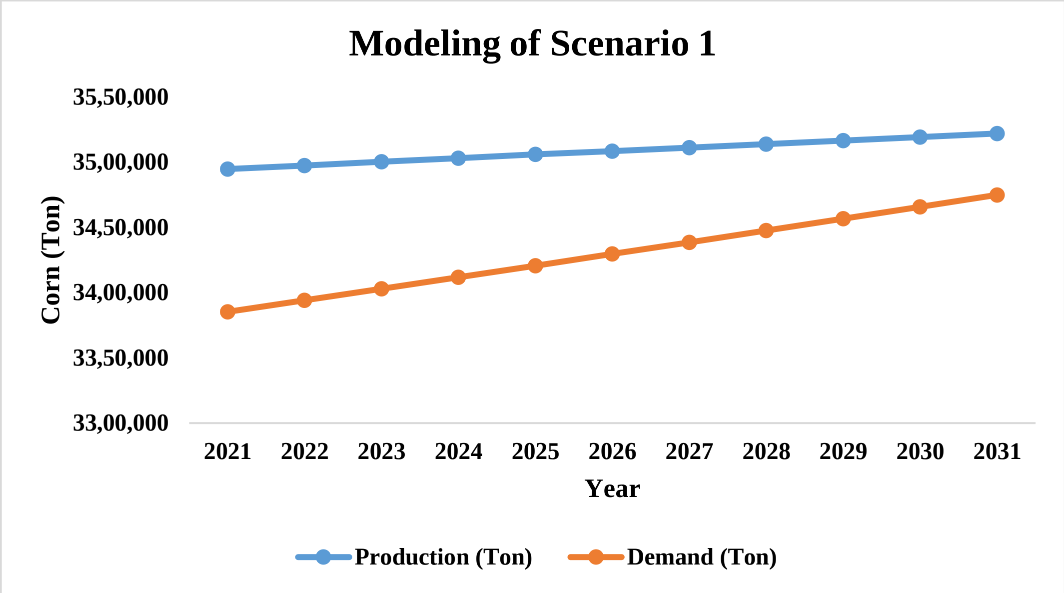

Table 6. Simulation result data of corn balance in scenario 1

Year	Corn Production (Ton)	Total Corn Demand (Ton)	Balance Sheet (Ton)
2021	3.494.592	3.385.229	109.363
2022	3.497.351	3.394.009	103.342
2023	3.500.102	3.402.829	97.273
2024	3.502.845	3.411.688	91.157
2025	3.505.845	3.420.586	85.259
2026	3.508.307	3.429.525	78.782
2027	3.511.027	3.438.504	72.523
2028	3.513.738	3.447.522	66.216
2029	3.516.442	3.456.582	59.860
2030	3.519.138	3.465.682	53.456
2031	3.521.826	3.474.823	47.003

Scenario 2 (Use of Superior Seeds and Drying Machine Technology)

Based on MT 1 cropping pattern, the main harvest occurs at the end of February, which coincides with the rainy season, so the use of drying machine technology is required to maintain the moisture content at 18% and corn can be stored longer. The use of a dryer can increase yield by up to 80%. Figure 7 depicts the simulation for Scenario 2.

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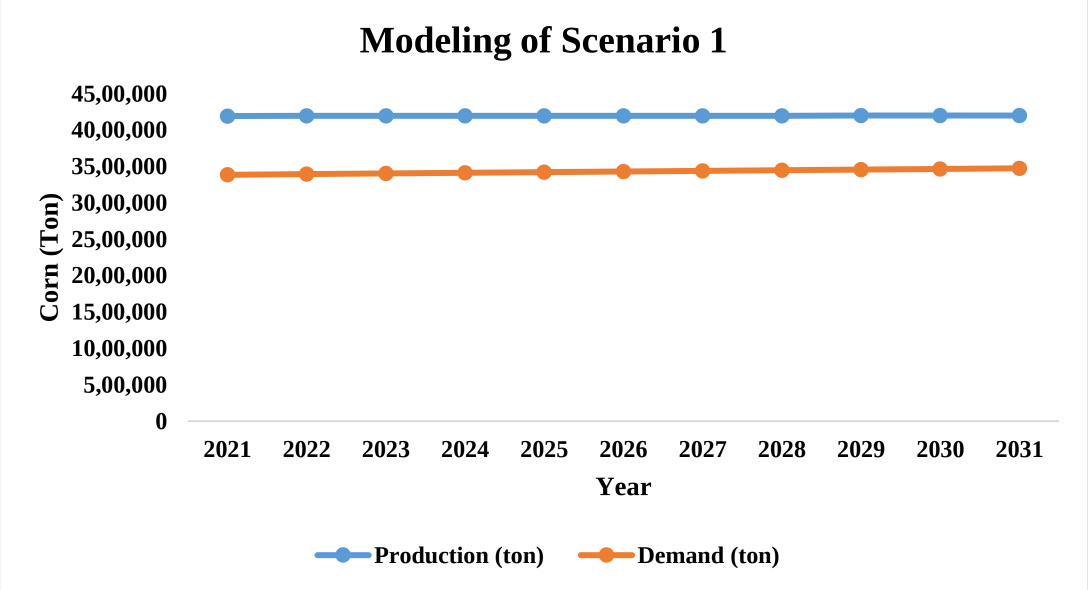
Figure 7. Growth of corn production and demand in Central Java under scenario 2



The movement of production behavior and demand for corn in Scenario 2 in Figure 7 shows that the production value is greater than the need value, implying that self-sufficiency can be achieved between 2021 and 2031. The use of dryer machines increases the total value of production based on a potential yield value of 11.44 tons/ha. In 2021, the surplus corn balance is 808,281 tons (Table 7). In Scenario 2, modeling was done by analyzing superior hybrid corn seed farming and using dryer technology. Based on the results of the farming analysis, the R/C ratio for scenario 2 is 3.42. The use of hybrid corn seeds and dryers produces greater economic benefits than the use of superior hybrid seeds without the use of dryers.

Table 6. Simulation result data of corn balance in scenario 1

Year	Corn Production (Ton)	Total Corn Demand (Ton)	Balance Sheet (Ton)
2021	4.193.510	3.385.229	808.281
2022	4.194.190	3.394.009	800.181
2023	4.194.868	3.402.829	792.039
2024	4.195.544	3.411.688	783.856
2025	4.196.218	3.420.586	775.632
2026	4.196.891	3.429.525	767.366
2027	4.197.562	3.438.504	759.058
2028	4.198.231	3.447.522	750.709
2029	4.198.899	3.456.582	742.317
2030	4.199.564	3.465.682	733.882
2031	4.200.228	3.474.823	725.405

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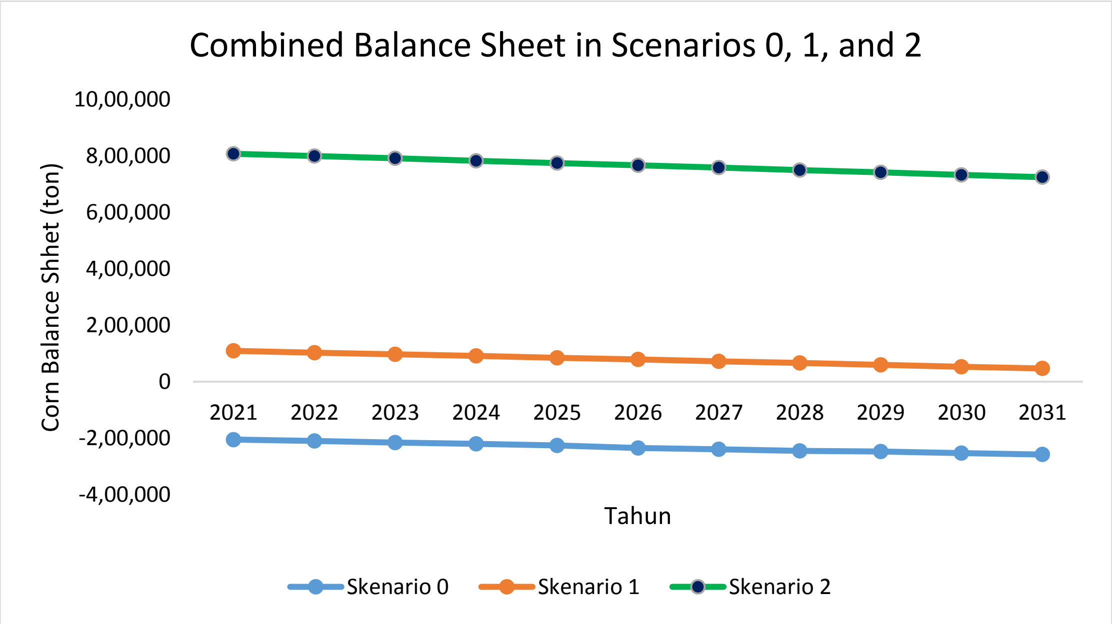
Combined Balance Sheet in Scenarios 0, 1, and 2

A graph can be used to depict the combined balance of scenarios 0, 1, and 2. Figure 8 shows that the scenario 0 balance sheet is consistently below the 0 line, indicating that self-sufficiency was never achieved. In contrast to scenario 1, self-sufficiency can be achieved in 2021, but the graph shows that the balance sheet value is decreasing, so it is predicted that the balance will again be in deficit in 2036. The results of Scenario 2 show that self-sufficiency can be achieved in 2021; however, the balance sheet continues to deteriorate over a relatively longer period of time.

The decrease in the balance line in scenarios 1 and 2 can be attributed to a variety of factors, including the limited amount of available corn harvesting land in Central Java Province, rising corn demand, and constant productivity value. According to the pattern of changes in the balance sheet in Figure 8, the self-sufficiency (UPSUS PAJALE) program in Central Java Province in 2021 has succeeded in directly meeting food needs, animal feed ingredients using the livestock population approach, and feed industry needs. However, sustainable self-sufficiency is impossible to achieve because the balance sheet graph lines for all scenarios continue to decrease year after year. According to(Majumder et al., 2022) dan (Sebayang, V., Sinagra, 2019), if there is no additional production, the decline in the commodity balance will be reduced.

Figure 8. Combined Balance Sheet of Corn in Central Java in Scenarios 0, 1 and 2



Model Deployment

The formation of various scenarios yields varying results. This scenario simulates data from 2012 to 2031 based on factors that have a direct impact on the amount of corn balance. Table 8 shows the differences in the outcomes of various scenarios.

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Table 8. Perbedaan hasil scenario

Scenario	Definition	Corn Production	Corn Balance Sheet	Self-Sufficiency
0	Actual Condition	Low	Deficit	Not Achieved
1	Increasing productivity with superior seeds	High	Surplus	Achieved
2	The use of superior seeds and drying machine technology	High	Surplus	Achieved

CONCLUSION

If Scenarios 1 and 2 are implemented, self-sufficiency can be achieved in 2021. Scenario 1 is carried out by increasing productivity by substituting composite corn seeds for hybrid corn seeds, whereas scenario 2 is carried out by planting hybrid corn seeds and employing drying machine technology (dryer). Central Java Province has been able to meet its own corn needs, which can increase the contribution of national corn production and achieve sustainable self-sufficiency. The decrease in balance each year in scenarios 1 and 2 indicates that sustainable self-sufficiency has not been achieved if other variables are not improved.

Recommendation

It is recommended that the Department of Agriculture for Food Crops in Central Java Province provide intensive assistance related to increasing corn productivity, one of which is the use of superior seeds and the use of drying technology.

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