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Study of Food Security in South Minahasa Regency Using System Dynamics

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Abstract. The definition of food security according to Law no. 18/2012 concerning Food, are: "The condition of the fulfillment of Food for the state to individuals, which is reflected in the availability of sufficient food, both in quantity and quality, safe, diverse, nutritious, equitable and affordable and does not conflict with religion, belief and community culture, to be able to live a healthy, active and productive life in a sustainable manner". Food security is thus a system with subsystems of availability, distribution, and consumption. System dynamics is a modeling method whose use is closely related to the dynamic tendencies of complex systems, namely the behavior patterns generated by the system over time. The main assumption in the system dynamics paradigm is that the dynamic tendencies that are continuous in any complex system originate from the causal structures that make up the system. In this study, the dynamic system modeling method is used to identify the behavior of the regional food security system in South Minahasa regency with the aim of analyzing the dynamics of the causal relationship of the variables that affect the food security system in terms of production, consumption, and rice stock in South Minahasa regency by using an approach systems and application of dynamic systems modeling techniques. In this study, a Causal Loop (CLD) and the Stock-Flow Diagram (SFD) were developed for the rice availability system based on the relationship between the production sub-system, consumption sub-system and the government's rice reserve sub-system involving the relationship of a number of variables to produce a model output in the form of projections of rice availability in South Minahasa regency for the period of 2020 to 2121. The results shows that food availability in period of terms of rice production in South Minahasa regency is very sufficient for the 2020 -2120 period, and there is even a surplus every year of 400% at the average.

INTRODUCTION

Efforts to understand the behavior of real-world systems have always been necessary in determining a policy or decision to be made regarding the management of the real-world system at hand. One of the real world phenomena that needs to be understood is the food system to support the food security of a region. There are various components involved in the food system with the aim of food security in a region. These various components interact with one another (cause and effect) in the form of positive or negative influences. In the food system, the larger component of paddy field planting area, for example, will have a positive influence on the availability of grain. On the other hand, a decrease in the area of rice fields due to the conversion of its use will have a negative effect on the production and availability of grain. Furthermore, the use of technology in the form of superior varieties will have a positive effect on the availability of grain because it can produce more harvests. If the number of components that make up a system studied is not much, it is relatively easy to understand the behavior of the system from the interactions that exist between system components. However, the more complex a system, the more difficult it is to understand the behavior of the system.

The food security system of an area can be said to be a complex system so that tools are needed to be able to understand the behavior of the system over time. System dynamics is a tool (methods) that can be used to study the behavior of complex systems. The use of a dynamic system approach in studying systems is growing with the support of computer technology. Thus, the behavior of the system over time is studied by means of a computer simulation, not directly in real-world conditions. Studying the behavior of the system by means of computer simulation allows experimenting with various scenarios of the structure of the system, and then selecting the scenario that gives the best or the desired results.

This research was conducted to study and develop a food security system structure in South Minahasa Regency using a computer-aided dynamic system approach to obtain the best scenario in an effort to produce a food security system that can be implemented. South Minahasa regency was chosen as the location of this research considering that the area underwent various rapid changes and threatened it carrying capacity and productivity in producing the main food ingredient, namely rice as one of the main agricultural products of South Minahasa regency. The ever increasing of rice consumption in one side and a decreasing capacity to produce rice in another side can create food insecurity conditions in the form of insufficient rice stocks inevitable.

RESEARCH METHOD

This research will be carried out using a dynamic system approach which includes stages of activities that include problem formulation, identification of important factors, conceptual model development, system dynamic model development, model simulation, model validation and implementation of results. The dynamic system approach in this study was carried out with the help of supporting software, namely Vensim PLE.

The model validation is carried out using the mean absolute percentage error (MAPE) method which has the following equation:

$$MAPE\ (\%) = (\frac{100}{n}) \sum_{t=1}^{n} |Dt - Ft| / Dt \quad (1)$$

where Dt is the actual value, Ft is the estimated value of the model, n is the amount of data. If the MAPE value <10% then the model estimation is very accurate. As the MAPE value is moving higher than 10%, indicating that the model estimates are increasingly inaccurate.

RESULTS AND DISCUSSIONS

South Minahasa Regency

South Minahasa regency is part of North Sulawesi Province with an area of 1,456.46 km2, with a population density in 2020 of 334 people/km2, spread over 17 districts, and 177 villages. The agricultural sector is still the largest contributor to the GRDP of South Minahasa regency, which is about 27% of the total GRDP. This condition shows the important position of the agricultural sector for the economy of South Minahasa regency, with 40.72% of land for food crops, 12.95% of plantation crops, 17.30% for other forms of agricultural activities, including inland fisheries. 22.88% of the total area is in the form of forest. Based on data from the Central Statistics Agency (BPS), South Minahasa regency's agricultural land area reaches 53,473 hectares. The total consists of 5,810 hectares of rice fields, 29,064 hectares of gardens, and 16,299 hectares of fields.

South Minahasa regency is supported by a wet tropical climate with rainfall ranging from 2000-3000 mm, and the average number of rainy days per year is 90-130 days.

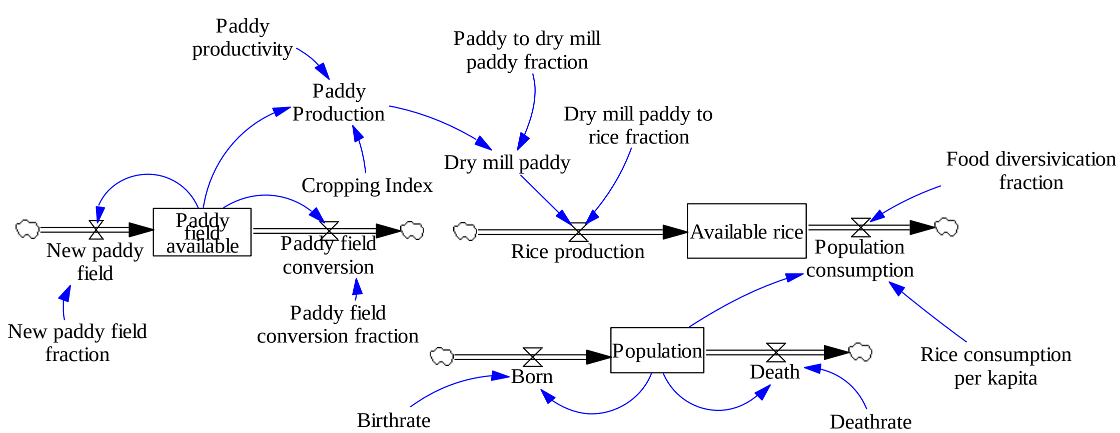

FIGURE 1. System Dynamics model of rice availability in South Minahasa regency

Paddy Cultivation

The main food crop cultivated in South Minahasa Regency is paddy with planting area of 5,810 hectares of mixed irrigation system of paddy fields. With the support of the existing irrigation system, partly of rice cultivation in South Minahasa has the potential to have a cropping or planting index greater than 1, meaning that it can be planted more than 1 time per year on the existing paddy fields. However, the condition of paddy fields in South Minahasa regency from 2010 – 2020, indicates a potential decrease in paddy field area, mainly due to the conversion of land to non-paddy fields or even non-agricultural uses. The average production per hectare of lowland rice in South Minahasa is 5.5 tons of Dry Harvested Padi (GKP). With the conversion rate from GKP to Milled Dry Grain (GKG) of 79%, resulting 4.35 tons of GKG per hectare, or equivalent of 2.43 tons of rice per hectare.

System Dynamics of Rice Availability in South Minahasa Regency

In principle, the development of the dynamic system model of rice availability in South Minahasa regency constitutes of three subsystems, namely the South Minahasa regency Population Subsystem, the South Minahasa regency Rice Production Subsystem and the South Minahasa regency Rice Availability Subsystem, with the cause-and-effect relationship depicted in Figure 1.

Figure 1 at the same time shows the dynamic system model of rice availability in South Minahasa regency with its three basic constituent subsystems. The three basic subsystems are the first step in testing the validity of the basic model of the rice availability system in South Minahasa regency, which can then be the basis for developing a more complex level system. All parameters used in the model is presented in Table 1.

TABLE 1. Parameters used in the model

Number	Variables	Equations/Constants	Units
1	Initial rice available in stock	50,000	Ton
2	Rice production	Dry mill to rice fraction'* 'Dry mill paddy'	Ton
3	Dry mill to rice fraction	56	%
4	Dry mill paddy	Paddy to dry mill paddy (GKG) fraction'*'Paddy production (GKP)'	Ton
5	Paddy conversion to dry mill paddy (GKG)	79	%
6	Paddy production (GKP)	('Paddy field available'* 'Paddy productivity'* Cropping Index')	Ton
7	Paddy productivity	5.5	Ton/Hektar
8	Cropping Index	1.5	Dimensionless
9	Initial paddy field available	5,810	Hektar
10	Paddy field conversion	Fraction of paddy field conversion'* 'Paddy field available'	Hektar/year
11	Fraction of paddy field conversion	1.00	%/year
12	Consumption	Rice consumption per capita'* 'Population'	Ton/year
13	Rice consumption pe capita	0.133	Ton/person/year
14	Initial population	182,017	Person
15	Born	Birth fraction'*'Population'	Person/year
16	Birth fraction	1.79	%/year
17	Death	Death fraction'*'Population'	Person
18	Death fraction	1	%/year

Simulation of Rice Availability in South Minahasa Regency

Population Subsystem

The population subsystem model of South Minahasa regency was compiled based on actual data on the growth of the South Minahasa population between 2013 and 2020. The results of the model estimation on the actual value of the South Minahasa population are shown in Figure 2, which shows that the South Minahasa population estimation model has a high level of accuracy with MAPE value 1.64%, that is way below 10%. Thus, the model is considered accurate to be used in estimating the population of South Minahasa regency in the future.

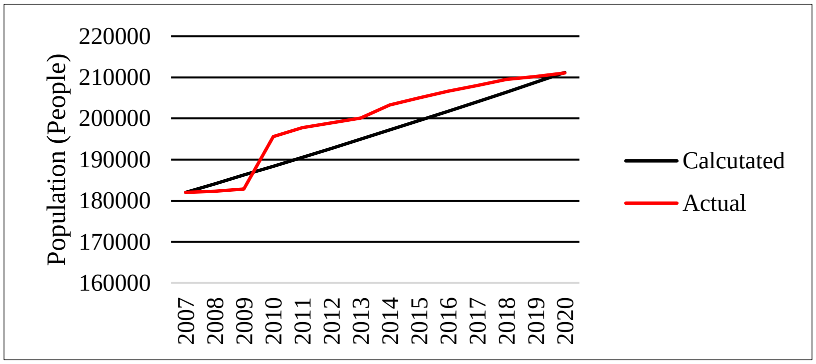

FIGURE 2. Actual vs estimated population

The estimation of the population of the South Minahasa regency population using a dynamic system model for the period of 2020 to 2120 is shown in Figure 3, which shows the population growth towards a population level of 571,085 people in 2120. In these conditions the density level reaches at around 3 people per hectare, which means the density level is still far below 150 people per hectare as an indication of low density population.

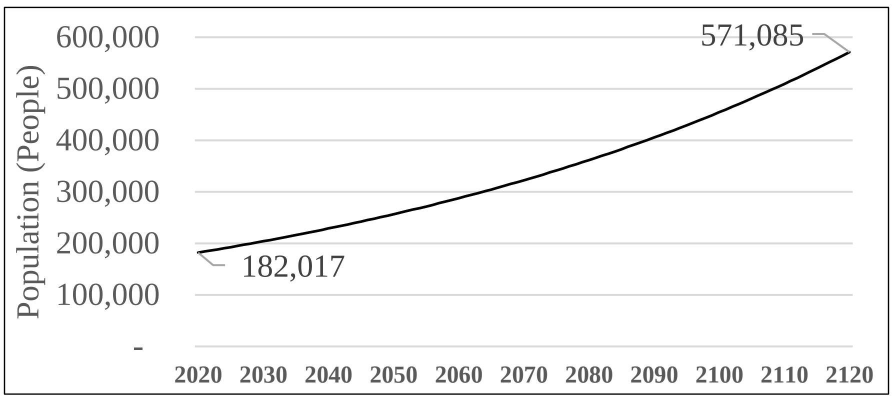

FIGURE 3. Growth of South Minahasa Regency Population 2020-2120.

Subsystem of Rice Production

The rice production subsystem model in South Minahasa regency is based on the involvement of several important factors, namely the availability of paddy fields per year which is influenced by the rate of land conversion. In addition, it is also influenced by the level of cropping index (planting intensity) per year which is largely determined by the ability of the irrigation system to provide water needs, and the productivity of rice plants per hectare to produce harvested dry grain (GKP). By using the parameters as shown in Table 1. the simulation result of the development of rice fields in South Minahasa regency between the period 2020 – 2120 is shown in Figure 4. This condition occurs assuming that the rate of conversion of paddy fields per year is at 1%, so that gradually the area of rice fields in South Minahasa will decreases. from initially 5,810 hectares in 2020 to 2,127 hectares in 2120. Instead, paddy field reduction will be slower and will decrease down to only 3,519 in year 20120 if there is program to create new paddy field as much as 0.5% per year.

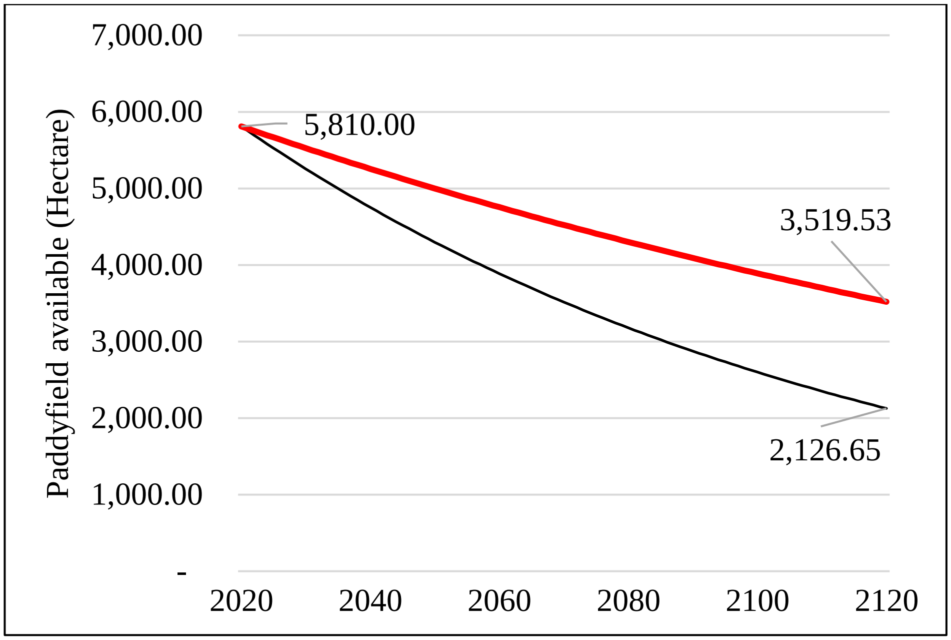

FIGURE 4. Trend of paddy field available in South Minahasa Regency

The above conditions are in line with the change in rice production level in South Minahasa regency during the period which gradually decreased as well, as shown in Figure 5. It will decrease from around 400 million tons in 2020 to just above 100 million tons in 2120. In the condition where there is program to develop new paddyfield at a rate of 0.5 % per year, the reduction of rice production will be slower and only down to more than 167 million tons in 2120.

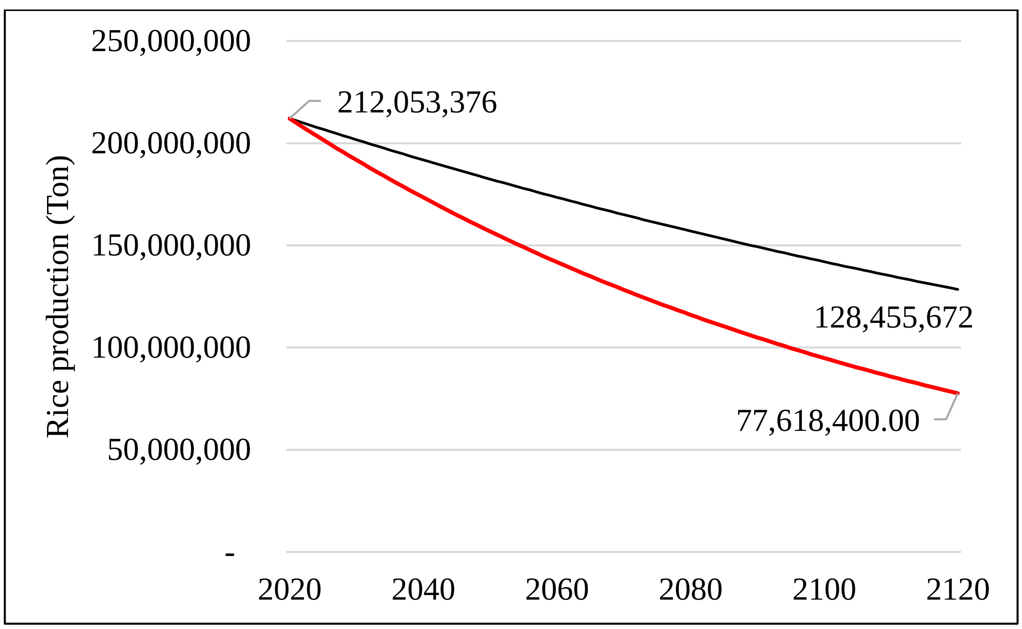

FIGURE 5. Rice production in South Minahasa Regency

Subsystem of Rice Availability

Furthermore, a dynamic system study related to the availability of rice in South Minahasa regency between 2020 and 2120 can be seen in Figure 6 which shows the consumption level of the South Minahasa regency population, which is in line with the change of the South Minahasa regency population (Figure 3). This consumption figure shows only less than 0.13% of the total existing rice production.

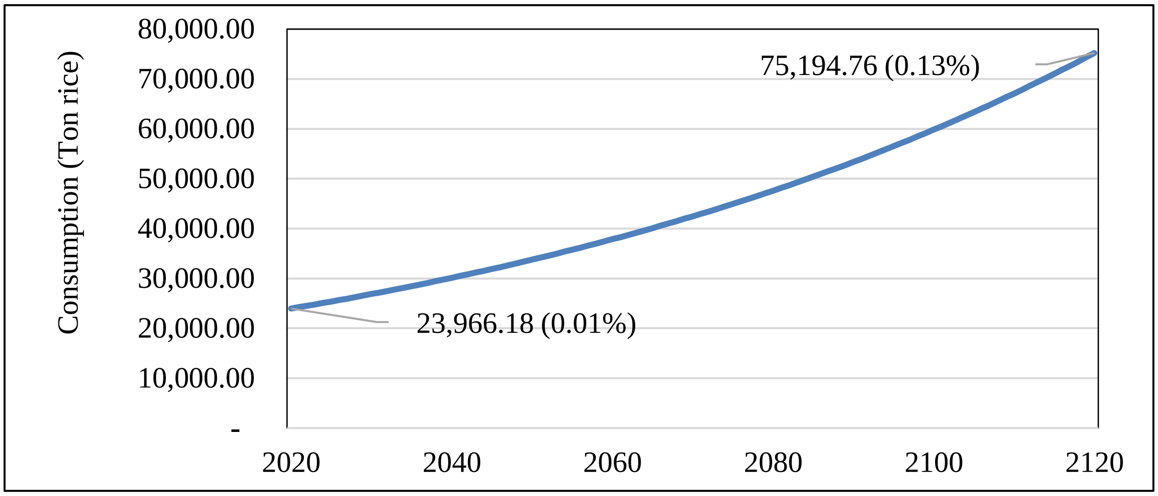

FIGURE 6. Rice consumption in South Minahasa Regency

Meanwhile, the change in rice availability in South Minahasa regency per year, between 2020 and 2120 is can be seen as in Figure 7, which at the same time shows that there is a surplus of rice in South Minahasa Regency per year. This shows that rice production in South Minahasa regency is still much more than what is required yearly for local consumption. This surplus need to be distributed to other areas that need rice supplies, or even for export.

The above conditions were achieved using paddy variety which is considered as low yields which produces around 5.5 tons paddy per hectares. Nowadays there are high yields variety of paddy available which can produce almost double than the existing one. With the high yield variety of paddy the paddy production will be much higher and of course that will improve the availability of rice in the region.

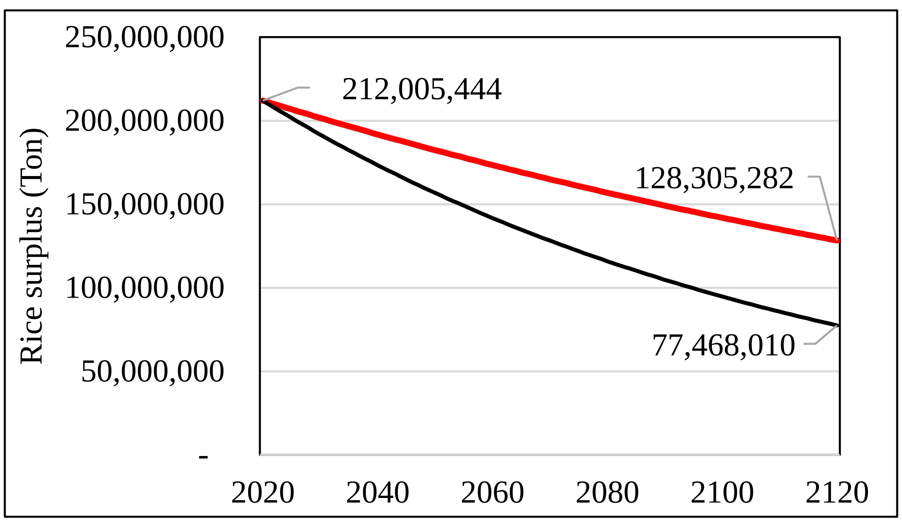

FIGURE 7. Rice surplus in South Minahasa Regency during 2020-2120

CONCLUSION

From the results of this study, it can be concluded:

1. System dynamics can be used to study the behavior of the food security system in South Minahasa regency in terms of rice availability quite well.
2. The estimation results show a tendency to decrease in area of rice fields due to land conversion. In line with that, there was a decline in rice production in South Minahasa regency.

3. The simulation for the period of 2020 to 2120 shows that rice production in South Minahasa regency can still meet the rice consumption needs of the South Minahasa population, and there is even a surplus of rice that can be exported to meet rice needs in other areas that is insufficient of rice.

RECOMMENDATION

The resulting System Dynamic Model is a basic model that still can be further developed to involve more various important factors that are not yet included in the current model.

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