

# Rice Development Availability Model using System Dynamics Method



Wahyu Sardjono, Lay Christian, Hanny Juwitasary, Edi Purnomo Putra

**Abstract** - Rice is a strategic food commodity in Indonesia, so the availability and consumption needs of rice need to be considered. In line with population growth and the decline in the area of agricultural land also influences the management of rice availability and has the potential to become a rice supply deficit if it is not managed properly. The purpose of this paper is to develop a pattern of relations between rice availability and rice consumption so that a balance occurs in the management of rice availability. The method used is the System Dynamics model, where this method is able to formulate a complex system by utilizing historically existing data to form a model, therefore this approach is expected to form a performance model of balance between rice availability and consumption which can then be simulated to predict needs in the future so that it can be used for faster and more accurate decision making.

**Keywords** - rice availability, system dynamics, model, simulation

## I. INTRODUCTION

For the condition of the people in Indonesia, the problem of rice is still a strategic commodity, because rice is still the largest main food component for the community in general, where in addition to the condition of the ever increasing population, the rate of decline in agricultural land tends to decrease [1]. This will affect the relationship between the amount of rice available which has the potential to be not proportional to the amount of consumption needed. (Figure 1.)

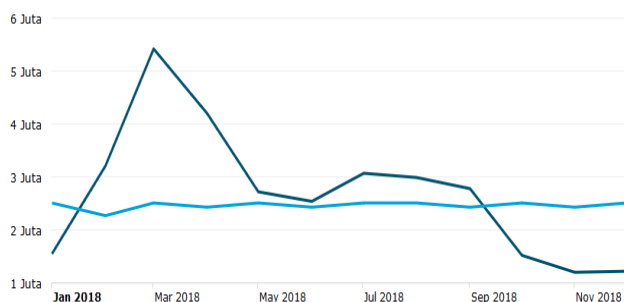


Figure 1. National Rice Availability and Consumption (Jan-Dec 2018), Source : BPS, 2019

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\* Correspondence Author

Wahyu Sardjono, <sup>1</sup>Information Systems Management Department, BINUS Graduate Program - Master of Information Systems Management, Bina Nusantara University, Jakarta, INDONESIA – 11480

Lay Christian, Information Systems Department, School of Information Systems Bina Nusantara University, Jakarta, Indonesia 11480

Hanny Juwitasary, Information Systems Department, School of Information Systems Bina Nusantara University, Jakarta, Indonesia 1480

Edi Purnomo Putra, Information Systems Department, School of Information Systems Bina Nusantara University, Jakarta, Indonesia 11480

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The Central Bureau of Statistics released national rice production data from January to September 2018 when converted into rice with the rate of dry rice paddy conversion to rice equivalent to 28.47 million tons of rice. While the potential for rice production in October-December was 1.52 million tons, 1.2 million tons and 1.22 million tons respectively. So the total rice production from January to December 2018 is estimated to reach 32.42 million tons. By looking at the data as presented in the picture above, it is necessary to try to build a model that can provide the following:

1. Providing insight to the decision makers of rice production to balance rice consumption in the community.
2. Get accurate insight into rice production in balancing the consumption of rice in the community

Progress and lack of capital is a condition of imbalance between increasing demand and capital capacity to meet needs. In a situation of progress and lack of capital, there will be near-limit growth that can be eliminated or postponed if sufficient investment capacity is made. The model of progress and lack of capital, relevant to explaining a number of circumstances and organizations, from sales to production including availability management problems, shows the relationship between growth and decision making in capital investment, because it can graphically. [2]

## II. METHODOLOGY

### Thinking system

The thinking system is an approach that sees the world as a complex system, all interconnected, so that it is impossible to do only one thing [3]. Phases of system thinking and modeling development are:

1. Arranging the structure of a problem: is an activity of identifying problems, collection of data and information, and limiting the scope of the problem.
2. Causal node modeling: is an activity of making a framework to see the relationship between problems and see patterns of change more than just static images.
3. Dynamic modeling: is a system diagrammatic activity that shows potential sectors of the simulation model, making stock flow diagrams, making simulation and verification models.
4. Planning and modeling scenarios: is the making of scenarios that can help make decisions that are able to describe the future of a system, the influential power in it, and uncertainty in a scenario.
5. Application and organization: is an application of the model produced in the form of a decision maker.

## *Model and Simulation*

The model is a simplified abstraction from the real world so that only important parameters and variables appear in their form. A model can reflect or abstract from an object, process, situation or system. More broadly a model can reveal and explain the relationship between various components, actions and reactions and causal relationships [4]. Model describes the phenomenon of an object or an activity. This phenomenon is called an entity. If the model describes a company, that company is the entity. If the model describes fluctuations in the company's sales volume, the sales of the company are the entity [5].

The types of models [6] are divided into three parts, including:

1. An iconic model providing visualization or demonstration of the issues reviewed, examples of this model are graphics, pie charts and aerial photographs.
2. Analog model based on the similarity of symptoms shown by the problem and that which is owned by the model.
3. Symbolic or mathematical models Declare quantitative, mathematical equations that represent problems.

Use of the model can get the following benefits [7]:

1. The process of modeling can be a learning experience. It can be ascertained, on each project something new is learned about the physical system.
2. The speed of the simulation process provides the ability to evaluate the impact of decisions in a short period of time. Within minutes, a company operating simulation can be made in several months, quarters or years.
3. The model provides predictive power, a view of the future, which other information cannot provide.
4. The model is cheaper than the trial and error method. The modeling process is expensive in development time and the software and hardware needed for the simulation, but these costs are not as high as the costs caused by the wrong decision.

The action of using a model is a simulation. Simulation is the only practical way to test a model [8].

Some of the advantages of simulation:

1. Can be used to analyze large and complex real-world situations.
2. Simulation models are made for management problems and require management input. Analysis that works on the model must deal extensively with the manager, this means users usually participate in the modeling process, and have a role in making it, so they are not afraid/hesitant to use it.
3. Simulation does not interfere with the real world systems.
4. With simulation can be studied the interactive effects of a component or individual variables to determine which is important.
5. Simulation allows time savings.

While the simulation also has disadvantages:

1. A good simulation model may be expensive. It is usually a long and complicated process.
2. Simulation does not produce optimal solutions to problems such as other quantitative analysis techniques.
3. Each simulation model is unique. Solutions and conclusions cannot be used for other problems.
4. All conditions and obstacles must be run to get the solution to be tested. The simulation model does not produce an answer by itself.

## *World Standard Model*

Of all the problems that can be modeled in the world in a nutshell it can be said that there are only 8 standard models that describe all the problems that exist in the real world, including [2] :

### **1. Fixes the fail**

Failure to repair is a quick action on a symptom that will unknowingly cause other consequences that will worsen the symptoms. An important component of this model is the delay. Often the influence of unintentional consequences only occur after some time, and it even takes longer before it is finally realized. In this system there are five elements, namely: actual events, desired events, problems, corrective actions and impacts. The difference in the desired event with the actual problem. The behavior shown in the model is Balancing.

### **2. Shifting the burden**

Load transfer is a quick (temporary) problem solving action that will unwittingly cause side effects which will worsen the symptoms of the problem. The model begins with a symptom of a problem that will make us more likely to apply problem solving problems rather than solving the real problem.

### **3. Limits to success**

The behavior that occurs in the system is balancing with a sigmoid pattern. Initially there was a growth that brought success. But with time, growth slowed and the system reached its limit. The nature of the sigmoid curve in this standard model is a combination of positive exponential growth at the initial stage and acystomatic growth in the final stage. The limiting factor is the characteristic of this model.

### **4. Drifting goals**

The behavior shown by the system is reinforcing. The model occurs because of a situation in which there are differences between the performance that is targeted and those achieved, then corrective actions are taken to increase or decrease the target / target. To eliminate these differences / differences, corrective / corrective actions can be taken that require resources according to time units.

### **5. Growth and under investment**

This model occurs as a result of the existence of an imbalance between the increase in needs and the capacity for capital growth to meet needs. In this situation, there will be near-term growth that can be delayed if the investment capacity is sufficient. Behavior in the demand graph is exponential growth while in capital is exponential growth which at a certain time collapses.

### **6. Success to the successful**

This model shows a state of competition in achieving success / victory. For those who succeed, there will be a tendency to increase their success by placing more resources. The behavior shown in the system is reinforcing.

7. **Escalation**

The model shows that there are two parties involved in a competition to outperform each other. The situation will show that each party will react to each other other to the actions of others. Each party will be threatened with each other with a continuous party that can increase pressure on both sides. This situation can be ended with a profit or loss for both parties.

8. **Tragedy of the Commons**

This model shows the existence of an event involving two or more parties who together use limited resources and get as much profit as possible. This condition will end with mutual difficulties. Model behavior is balancing.

**System Dynamics**

[9] Dynamic system is a simulation technology based on feedback theory used to study complex systems. This simulation technology is only used to predict the future from year to year according to certain parameters, cannot be used to estimate at the right level reliably.

Dynamic systems can be used to support learning management and decision making [10]. The system dynamic approach is an approach to modeling [11] that has the following advantages:

1. Have a Causal Loop Diagram (CLD) and Stock Flow Diagrams (SFD) which is formulated to show the natural state as well the direction of the relationship of each variable and sub-system in system dynamic.
2. Decision-making policies can vary based on simulation and system dynamic for a certain period. In addition, decision making can provide feedback within the system so that it can facilitate policy making.
3. Linear and non-linear relationships can be combined.
4. Physical and information delays can be combined.
5. Information can be entered to strengthen statistical data which sometimes cannot be directly used in the system.

**Causal Loop Diagram (CLD)**

Causal Loop Diagrams (CLD) can be used to record a model that represents the linkages and feedback processes in the system. (F.T. Yuan, 2010), (Behdad Kiani, 2009) states that the main purpose of the Causal Loop Diagram (CLD) is to describe the causal hypothesis, thus making the presentation of the structure in the aggregate form. CLD helps users quickly communicate the structure of feedback and the underlying assumptions. CLD is able to present how the system works. CLD has long been used in academics, and is increasingly being used in the business world, CDL is very good for:

1. Give a quick description of the hypothesis of the causes of dynamics.
2. Provide important, trusted input for a problem.
3. Triggers and describes the model for both individuals and teams.

Causal diagrams consist of variables that are connected with arrows to show causal influences between variables. A causal relationship describes one element that affects other elements.

Where the causal relationship is divided into two parts, including:

1. Positive relationship: a condition in which element A has a positive effect on element B, where an increase in value A affects the increase in value B.
2. Negative relationship: a condition in which element A produces a negative effect on element B,

where an increase in value A affects the decrease in value B. (Figure 2.)

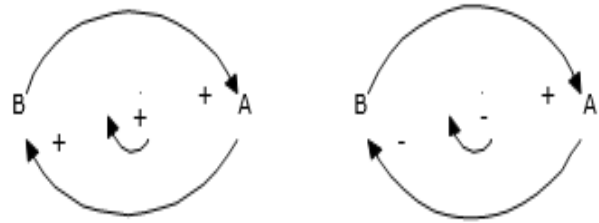


Figure 2. Causal Loop Diagram (CLD)

**Stock Flow Diagram (SFD)**

Stock Flow Diagrams (SFD) is a system that describes the relationships between variables. Below are symbols in the Stock Flow Diagram (SFD):

Table 1. Symbols in SFD

Symbol	Variable	Description
	Stock/State/Level	Accumulation
	Rate / Flow	Flow consisting of cloud elements (source origin or flow discharge), valves and flow channels
	Auxiliary	Symbols of constants or connecting calculations in model simulations.
	Constant	
	Causal Link	Variable representation as a cause or effect with or without delay associated with an arrow.
	Causal Link with Delay	

Source : System Dynamics Analysis, Muhammadiyah, 2001 Next, powersim software which is often used to support the development of decision support systems is used to support the development of this dynamics system model.

III. RESULTS AND DISCUSSION

The development of a system dynamics model is done by starting to build several assumptions including:

1. There is only population growth without the occurrence of a reduction due to natural deaths, wars or disasters.
2. Never implemented a number control program world population, for example through family planning programs.
3. There is only an increase in world food supply without any reduction.

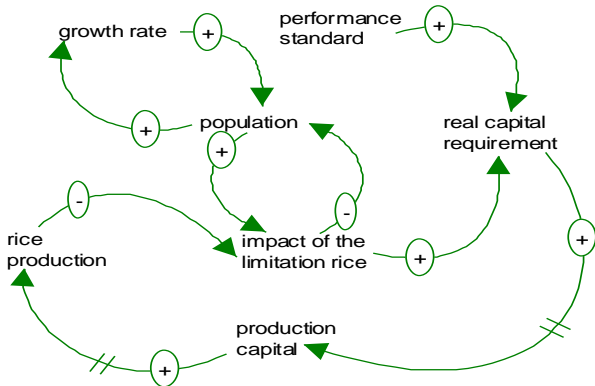
**Model Concept**

Initially rice production was able to meet the needs of the community, but over time there was a population growth with an increasing growth rate every year. the higher the rate of population growth, the higher the number of people increasing so that it will increase rice consumption and ultimately it will also affect the availability of rice. To overcome the gap between the availability of rice and the consumption of the population there needs to be a performance that is able to provide capital availability, so that limited availability can be addressed properly.



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For this reason, it needs to be harmonized between real capital requirements and performance standards. Through the causal loop diagram, the above conditions can be described as follows (Figure 3.)



**Figure 3. Rice Model - Causal Loop Diagram (CLD)**

Then by using existing time series data, such as commodity and rice data (Table 2.)

**Table 2. Rice Commodity**

year	commodity	rice
2010	harvest area (ha)	12,793,332
	Production (ton)	66,469,394
2011	harvest area (ha)	13,203,256
	Production (ton)	65,756,904
2012	harvest area (ha)	13,465,142
	Production (ton)	69,056,126
2013	harvest area (ha)	13,834,873
	Production (ton)	71,279,709
2014	harvest area (ha)	13,789,922
	Production (ton)	70,846,465

Also the existing time series data are related to the population (Table 3.) using the same assumptions defined above and taken for a certain period of time according to the table.

**Table 3. Indonesia Population**

Year	Population
2010	238,518,800
2011	241,990,700
2012	245,425,200
2013	248,818,100
2014	252,461,700
2015	255,461,700
2016	258,705,000
2017	261,890,900
2018	265,015,300

**Source : Central Bureau of Statistics, 2019**

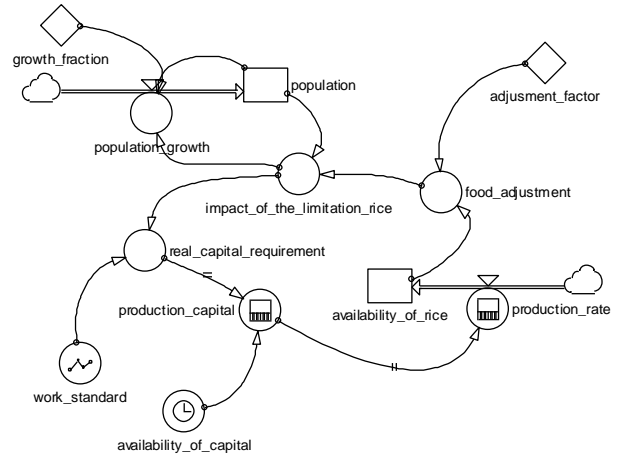
And also the existing time series data are related to the Rice Consumption (Table 3.) using the same assumptions defined above and taken for a certain period of time according to the table.

**Table 3. Growth and Rice Consumption**

year	consumption kg / capita / week	consumption kg / capita / year	growth %
2010	24,550	1,280,091	0
2011	25,739	1,342,087	4.84

2012	16,811	876,547	-34.8
2013	16,491	859,861	-1,90
2014	24,101	1,256,668	46,15

Henceforth, a stock flow diagram can be built based on a causal loop diagram that has been prepared and tested by utilizing the time series data availability for a number of variables owned (figure 4.)



**Figure 4. Rice Model – Stock Flow Diagram (SFD)**

*Simulation result*

The simulation results in powersim equations are :

```

init  availability_of_rice = 66469394
flow  availability_of_rice = +dt*production_rate
doc   availability_of_rice = The amount of food that is
      successfully produced every year
init  population = 238518800
flow  population = +dt*population_growth
doc   population = Population in a given year
aux   population_growth =
      (population+impact_of_the_limitation_rice)*growth
      _fraction
doc   population_growth = population growth at a certain
      time
aux   production_rate =
      DELAYINF(production_capital,1,1,0)
doc   production_rate = The amount of food that ican be
      produced every year
aux   availability_of_capital = IF(TIME<120,1,0.01)
doc   availability_of_capital = The amount of capital
      available for food production
aux   food_adjustment =
      availability_of_rice*adjsument_factor
doc   food_adjustment = the amount of rice produced and
      adjusted
aux   impact_of_the_limitation_rice = population-
      food_adjustment
doc   impact_of_the_limitation_rice = the large number of
      people supported by rice production
aux   production_capital =
      availability_of_capital*DELAYINF(real_capital_req
      uirement,1,1,0)
doc   production_capital = The amount of food available
      every year
aux   real_capital_requirement =
      impact_of_the_limitation_rice/work_standard
    
```

doc real\_capital\_requirement = the amount of capital in the form of food needed  
 aux work\_standard = GRAPHCURVE(TIME,0,20,[10,7.7,6.1,5,4.1,3.3,2.6,1.5,1.1,0.8"Min:0;Max:10"])  
 doc work\_standard = the time of growth needed by residents of each unit of food  
 const adjustment\_factor = 0.9  
 doc adjustment\_factor = Rasio between the number of people and the amount of food available  
 const growth\_fraction = 0.0075  
 doc growth\_fraction = constan that indicate the magnitude of population growth

natural resources as economically as possible, is the main requirement for the continued growth of the community.

#### IV. CONCLUSION

In a situation of progress and lack of capital there will be a near-limit growth that can be carried out if an investment of adequate capacity is made. however as a result of policy or a slowdown in the system, declining demand will limit further growth. The reduction in needs was followed by a reduction in investment capacity which led to worse performance

Based on the simulation results with the data, processes and assumptions that apply in the modeling of the management of the availability of rice made, it can be concluded as follows:

1. The raw model of Growth and under investment can be used to describe the behavior of rice availability models as an alternative control of the management sub-system of the relationship between the availability of rice and the consumption of rice by the community.
2. The public's bad behavior towards rice consumption, perception of the abundance of rice, and the limited availability of rice can cause conditions of imbalance.
3. The intervention of rice consumption can be done by adjusting the consumption of rice which refers to the condition of the available rice, so that a balance of rice consumption is achieved.
4. Changes that are quite effective occur after a sensitivity test has been carried out, this indicates that the availability of capital is a sensitive variable. Because this variable shows that the available capital influences the use of natural resources as economically as possible, is the main requirement for the continued growth of the community.

#### Model Analysis

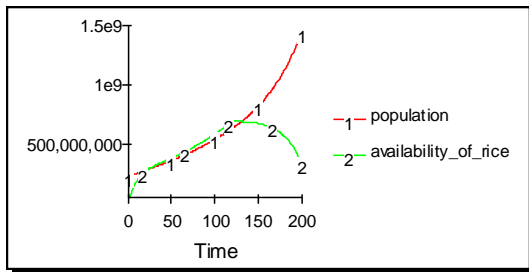


Figure 5. Graph the relationship between community growth and the availability of rice

#### Work Standard

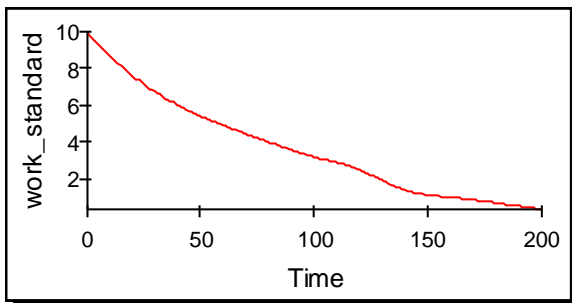


Figure 6. Graph of work standards for managing the availability of rice

#### Intervention Strategy

Based on the results of existing simulations, it is known that the tendency of abnormal conditions will occur in the next few years which means that it will threaten the balance of the availability of rice, an intervention strategy is needed to maintain balance, the results of this intervention strategy can be seen in figure 7.

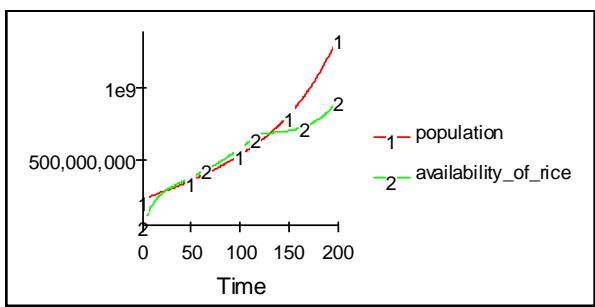


Figure 7. Graph of performance standards for managing the availability of rice

Changes that are quite effective occur after a sensitivity test has been carried out, this indicates that the availability of capital is a sensitive variable. Because this variable shows that the available capital influences the use of

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### AUTHORS PROFILE



Wahyu Sardjono is currently working at BINA NUSANTARA University, INDONESIA, as a Senior Lecturer at Information Systems Management Department, BINUS Graduate Program - Master of Information Systems Management. Experienced in teaching from 2004 until now. He is a PhD holder from University of Indonesia, INDONESIA (UI) in Environmental Science. In addition, he got the Master in Master of Management (e-Business) from University of Gadjahmada, Yogyakarta (UGM) and Bachelor in Applied Mathematic from Institute of Technology Bandung (ITB). Research interest includes environmental management, Green IT, modelling, and Knowledge Management. Having 8 Publications in Scopus Journals. Completed 4 projects and has a vast experience in the field of knowledge management and natural disaster mitigation.