Supply and Demand of Rice in Malaysia: A System Dynamics Approach

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***Abstract*— This paper illustrates the development of a supply and demand model of rice in Malaysia to gain better understand on the factors that affect the rice supply and demand towards the rice production system in Malaysia. It is known that the population of citizens in Malaysia relies heavily on the rice as its staple food for daily consumption. Currently, Malaysia has about 75% rice self-sufficiency level (SSL). The Malaysian government has set a target of 100% rice SSL in the production to meet the demand of the growing population. In this study, the qualitative approach of system dynamics is employed to analyze the effect of the price, land availability and technology on the rice production in Malaysia by using the causal loop and stock flow diagrams. The finding of this study will be helpful to assist the government in better understand the causes and effects of the factors related to improve the policies of the production of rice in Malaysia.**

***Keywords*—** *Supply and demand, rice self-sufficiency level, system dynamics, causal loop diagram, stock flow diagram.*

1. Introduction

Rice has been the staple food for so many countries all around the world that acts as the sustaining food for the population. From a humble beginning of basic cultivation of paddy by the farmers to a modern approach of science and specialized technologies, the production of rice has transformed immensely to meet the growing demand from the consumer. Rice is particularly a fundamental part of the daily consumption for the Southeast Asia countries, including Malaysia. Rice can be claimed as the essential part of the local culture as rice has been planted and consumed for decades. The rice production in Malaysia is very important in terms of providing and supplying the primary food for the people based on the growing demand and population. Not only contributing in the social aspect, it also benefits in terms of economics by providing jobs and opportunity to the farmers. Sustaining the rice production is very important in balancing both the social and economic sector. Thus, maintaining a sustainable rice production in the country is very crucial. Figure 1 shows the increasing population of Malaysians from year 2000 to 2014. Consequently, it also shows the increase in the domestic consumption of rice in the same years. Thus, it indicates that as the population increases, the domestic consumption also increases. The need to sustain the production of rice is very vital in order to meet the increasing demand of rice from the growing population [1]. Malaysia currently produces approximately at 75% of rice for local demand annually, with the remaining sourced out from several countries, including Thailand, Vietnam and Pakistan. However, the national average yield is low at just over 3.0 tons per hectare. Local production can only cater approximately 60-65% of domestic requirements. Hence, the shortfall is supplemented by imported rice.

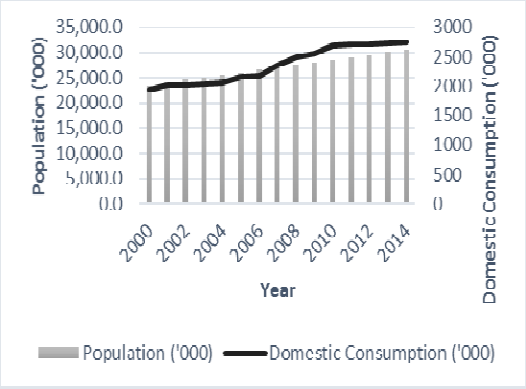

Figure 1. The trend of the population & domestic consumption of rice [2]

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On the other hand, Figure 2 shows the quantity of rice that had been supplied to the local consumer. It shows the fluctuation; in which regular increment of rice is supplied in Malaysia over the years. The supply of rice from local production is supported with the import rice to meet the demand of the increasing population in Malaysia.

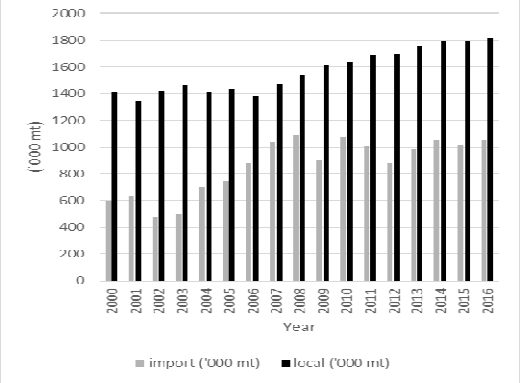

Figure 2. The trend of the import rice and local rice [2]

A steady increase in the rice supply by the local production has been shown starting from year 2007 to 2016. The comparison of the rice supply between year 2007 and 2014 has been shown in Figure 3 below. The local production had increased by 4% within 7 years. However, it is still insufficient to satisfy the demand from the local consumer as the data shows that Malaysia still receives the import rice supply as to support the growing demand.

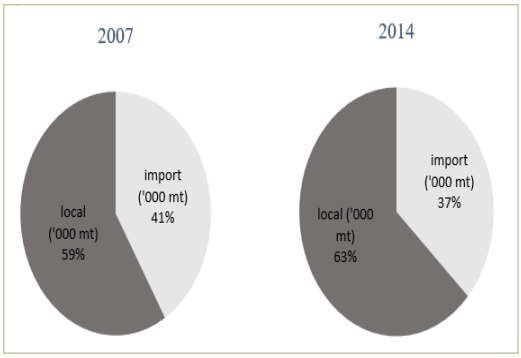

Figure 3. Rice supply in Malaysia

Additionally, government had allocated RM1.3 billion subsidies to the paddy farmers which includes the price subsidy, seed subsidy and fertilizer subsidy [3]. Thus, to fulfil the demand for the growing population, Malaysia should sustain its production by maintaining or increasing the rice productivity. The recent crisis has highlighted the need to pursue more aggressive policies to enhance the rice production through expansion in domestic production and lesser dependence on imports. It is also not in the long-term interest of the country to be increasingly dependent on external sourcing for food, as there is uncertainty in its long-term international supply.

Nevertheless, the country cannot fully depend on the import of rice to replenish the remaining required rice supply to the local consumer. This had been proven by the global food crisis that attacked the Asian countries in 2008 that had led to a concern as the importers refused to export their production out of the countries [4]. The importance of rice production in Malaysia has directed our country to the formation of policy regarding the sustainability of the local national rice production instead of depending on the import from other countries. The government must not overlook on the impact of the crisis to the rice production industry. If the history is repeated, Malaysia needs to have a strong policy in the rice production system to avoid the dependency from other countries and to ensure a sufficient supply to the local consumers.

2. Purpose of Study

As discussed earlier in previous sections, there are several factors that affect the demand and supply of rice in Malaysia such as price, land availability and technologies. All these factors are interdependent and dynamic through time which caused the dynamic complex behavior in the rice production system. There are various past studies regarding the rice production in Malaysia that had discussed the resource allocation production in increasing crops production [5] and the correlation between rice self-sufficiency and rice production (per capita) [6]. However, these studies did not discuss the cause and effect relationship of the factors which affecting the rice production.

System dynamics is a suitable approach to study the rice production system where the complexity of the factors is interrelated and continuously changed dynamically through time. System dynamics involves the ability to represent and assess the dynamic complexity of the behavior that arises from the interaction of a system's agents over time. Thus, the purpose of this study is to employ the system dynamics methodology to develop the causal loop and stock flow diagrams of the supply and demand in rice production in Malaysia. The

aim of the developed qualitative model is to gain better understand on the fundamental factors that affect the rice production system in Malaysia.

3. Literature Review

3.1. Issues in Demand and Supply of Rice in Malaysia

Several factors have reportedly influenced the rice production in Malaysia. Any negative interference on the factors will cause a massive challenge in sustaining the rice production in the country. The challenges included changes in climate, dependent on the economic rule, high production cost, lack of land availability, dependency on subsidy and inadequacy in technology and infrastructure. Climate is uncontrollable, and the changes are unpredictable. The yield, cultivated area and value of rice crop are affected by the climate factors such as temperature, rainfall and soil moisture [7]. In contrast, the average production cost in Malaysia is higher than the price of rice in the international market itself [4]. Hence the high level of dependency on the imported rice from other countries which showed that the production venture is just highly expensive and not cost efficient.

However, the problem with the dependency on other countries is that Malaysia is exposed to export restrictions as we rely on the market for supplies. As mentioned before, the food crisis in 2008 had proven that the dependency on others considered to be a huge challenge when other countries refused to supply the rice to us. Apart from that, in order to produce rice, a suitable paddy production area and an efficient water system Malaysia are vital. Yet, Malaysia lack the areas that own large scale river system to produce the high level of rice production [8]. A study by Rashid and Dainuri (2013) showed that productivity and farm size of the rice industry in Malaysia is relatively low [4].

The main purpose of meeting a high-level rice production is to achieve a total rice self-sufficiency. Rice self-sufficiency level is the ability of the country to be able to supply rice one's own or its own needs without external assistance from other countries. Self-sufficiency is achieved when production exceeds consumption. When a 100% rice self-sufficiency level have been met, Malaysia no longer needs to import the rice from other countries such as Thailand, Vietnam, Cambodia and India. The current rice self-sufficiency level in Malaysia is set at approximately 75% [9], while the balance percentage of rice is sourced mainly from Vietnam, Thailand and Pakistan with the net rice imports grow by 2.2% per year by 2021 [10]. Due to the dependency on other countries, Malaysia targets to reach a 100% rice self-sufficiency level by year 2020.

3.2. System Dynamics Studies Related to Rice Production System

System dynamics is a computer-based approach to understand and analyze a system's behavior over time. Complex dynamic problems can be studied with this method as the system can be applied to diverse fields of study such as healthcare [11], strategic planning [12] and education [13]. The traditional correlation method used in food production study should preferably be replaced with system dynamics approach as it takes deep interest on the causation of the problems and the evaluation of policies and long term influence [14]. Thus, it can be assured that the use of system dynamics in the study of rice production is suitable.

The other study is the usage of system dynamics to overcome the shortage in production and supply of rice in Egypt [15]. Policies was tested in terms of the productivity, losses, population growth and annual income. Another study that used system dynamics is the long-term effect of fixed price and exchange rate policies that identified for the food self-sufficiency in Iran. The floated price and exchange rate are applied as the counter policies in order to test the existing policy [16].

In Malaysia, there are few researchers that had used system dynamics in the rice production system. One of the studies are based on the impact of fertilizer subsidy on Malaysia rice industry that consists of yield as the main outcome [17]. Another study on the production of rice in Malaysia emphases on the relationship of four factors which are the fertilizer subsidy, physical loss, paddy area conversion and land fertility [18]. Six different scenarios had been simulated to see the outcome when those changes had been made. However, there are very few studies related to rice production that focus on price, land availability and technology. Thus, this study adopted system dynamics to study the rice production based on

those three factors. It is apparent that system dynamics is a very reliable method in analyzing the rice production system.

4. System Dynamics Methodology

Based on the principal of system thinking, system dynamics involves the ability to represent and assess the dynamic complexity of the behavior that arises from the interaction of a system's agents over time both textually and graphically [19]. Plus, it is also a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects. These skills work together as a system [20]. Hence, system dynamics is appropriate in the study of the rice production system which shows the complexity of the factors that are interrelated and change dynamically through time.

Figure 4 shows the system modelling process that is used to study the rice production system in Malaysia. It involves the five stages which are problem articulation, formulation of dynamic hypothesis, formulation of formal model, model testing and policy design and evaluation. It is an iterative process where constant process of modelling, testing and refinement are conducted through the model development [21]. All the stages are grouped into two approaches namely qualitative and quantitative. The qualitative approach emphasizes on the conceptualization of the model while the quantitative approach focuses quantifying the aspect of the model. However, this study will only focus on the qualitative aspect of rice production system in Malaysia which are problem articulation and formulation of dynamic hypothesis.

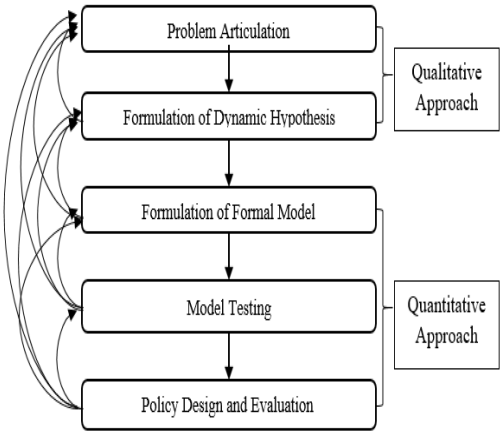

Figure 4. The iterative system dynamics modelling process

4.1 Problem Articulation

The development of system dynamics model starts with the problem articulation. This stage involves the determination on the purpose of the model, the model boundaries which are the time horizon and key variables, and setting the reference mode. The purpose of this study is to model the supply and demand of the rice production system and to analyze the factors that affect the production which focuses on three factors namely price, land availability and technology. The reference mode of this study has been shown earlier in Figure 1 and Figure 2.

Next, the key variables are identified. Figure 5 shows the key variables of the rice production system in Malaysia. The structure of the model is divided into five sub components; local production and the three factors affecting the production, import, supply, demand and self-sufficiency level.

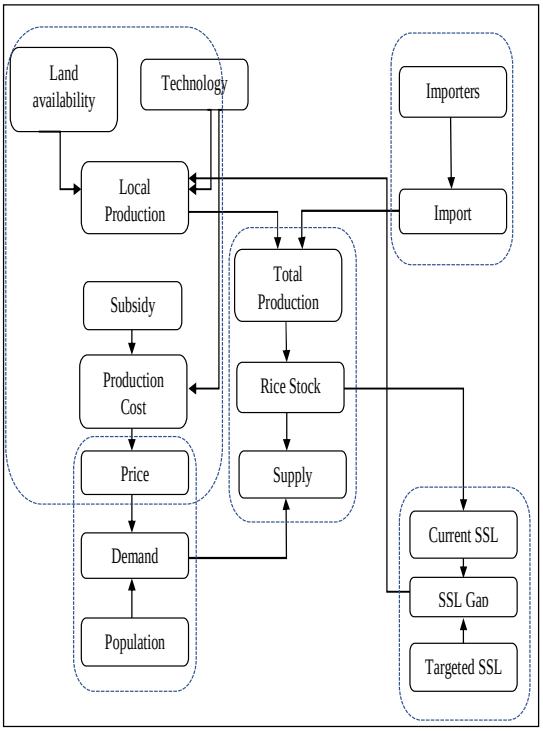

Figure 5. Preliminary model structure of supply and demand of rice in Malaysia

Furthermore, every variable can be classified into three types namely endogenous, exogenous and excluded. An endogenous variable exists within the sytem boundaries while the exogenous variable exists outside the system. Excluded variable is the variable that is not included in the system [21].

Table 1 shows the classification of the variables focus in this study.

Table 1. Classification of variables

Endogenous Variables	Exogenous Variables	Excluded Variables
Rice stock Demand Supply Local Production Land availability Population Subsidy Production Cost	Import SSL SSL Gap Targeted SSL Price Technology	Climate change

Two types of data are used to analyse the variables involved in this study namely primary data and secondary data. The primary data is collected through the interviews with the stakeholders directly involved in the rice production industry, such as the farmers, the Ministry of Agriculture and MARDI. The secondary data is extracted from the public open sources such as Department of Statistics Malaysia, Index Mundi and other relevant internet sources. This data is calibrated in the model development of rice production system in Malaysia.

4.2 Formulation of Dynamic Hypothesis

The modelling process continues with the development of the causal loop diagram (CLD). The elements of the system and its interaction is important in system dynamics. CLD explains the behaviour and the qualitative side of the system by showing a group of nodes that are interconnected by arrows and the feedback loops created by the connections [21].

The relationship between every interrelated variables are explained based on the reference mode. For example, Figure 6 shows the relationship between the area harvested and the local production. It is assumed that as the area or land available increases, the local production of rice is also increase. It is proved by Figure 6 that shows the increment of local production as the area harvested increases. This relationship is then translated into the causal loop diagram to show the behaviour of the system by the nodes of the variables that are interconnected by arrows and the feedback loops.

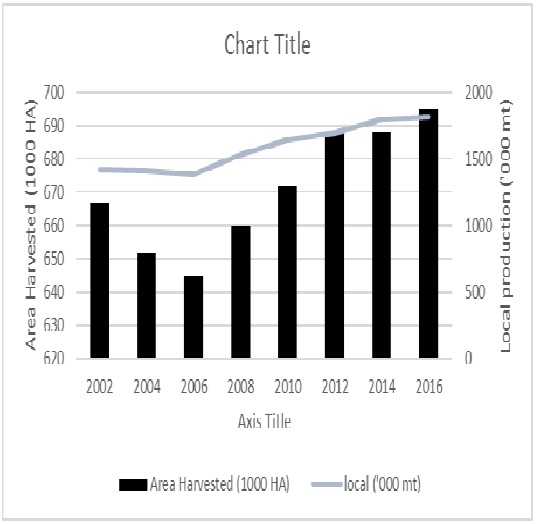

Figure 6. The relationship between the area harvested and the local production of rice [2]

Figure 7 shows how the variables in the rice production system affect one another. The positive sign (+ve) indicates the changes of the variables in the same direction while the negative sign (-ve) shows that the variables change in the opposite ways [21]. For example, the population and the demand have a positive sign relationship. It shows that as the population increases, the demand also increases. While the negative sign relationship between the local supply and SSL Gap indicates that as the local supply increases, the SSL Gap decreases.

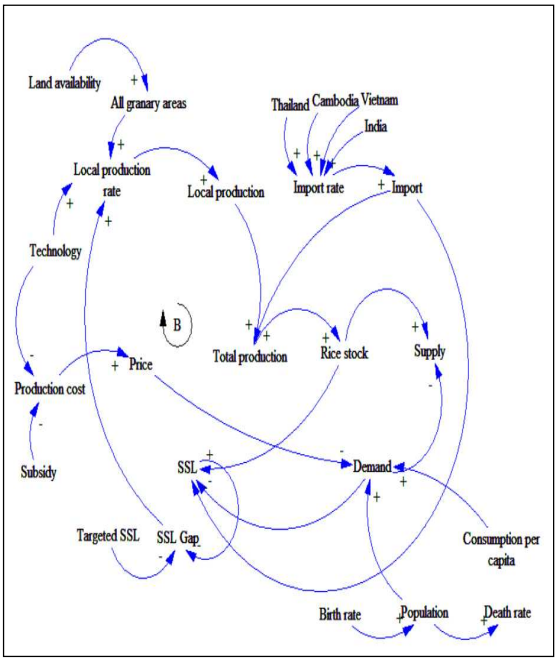

Figure 8. The stock flow diagram of supply and demand of rice in Malaysia

For instance, rice stock represents one of the stocks of the system. The inflow is represented by the total production while the supply represents the outflow. The stock accumulates the effect of the flows and will remain unchanged if there are no flows to increase and the current level of stock. The total production will increase the rice stock while the supply will decrease the rice stock as seen in Eq. (1).

The total production is the total of the import and local production. Import comes from the imported rice from various countries. While the local production comes from the locally produced rice in Malaysia. The local production rate depends on the three factors studied in this research namely land availability, price and technology. Ultimately, the increase in the local production will increase the rice self-sufficiency level (SSL) in Malaysia as seen in Eq. (2). The need to meet a 100% rice SSL is motivated by the increasing demand of the increasing population in Malaysia that is shown by the population stock in the diagram.

Other variables that act as the auxiliary (intermediate variable) breaks the flow equation into smaller part. As mentioned before, there are three factors that represent the factors that affect the rice production system; price, land availability and technology appear in the system. The achievement of 100% targeted SSL will be indicated by the SSL Gap in the figure. For example, if the current Local Supply is at 70%, the SSL Gap is 30%. Thus, the three factors in the system need to be evaluated and tested to improve the policy to achieve a 100% SSL of rice production in Malaysia.

Accordingly, below shows some of the equations for the stock flow diagram.

Rice stock = A FUNCTION OF(Rice stock, supply, Total Production)
Rice stock = INTEG(Total production-Supply) (1)

SSL = (Rice stock – Import)/Demand (2)

*Demand = Population*Consumption per capita*Price*(3)

Local production = INTEG(Local Production Rate) (4)

Import = INTEG(Import Rate) (5)

Population = A FUNCTION OF(Population, Birth Rate, Death Rate)
Population = INTEG(Birth Rate – Death Rate) (6)

5 Conclusion and Future Work

This paper has illustrated the development of the causal loop diagram and the stock flow diagrams of the supply and demand of rice in Malaysia to assist in better understand of the rice production system in Malaysia. This study focuses mainly on the qualitative approach of the system dynamics that involves the development of causal loop diagram and stock flow diagram in analyzing the causal and feedback relationship between factors. The three factors have been studied in this study that affect the rice production are the price, the land availability and the technology. The future extension of this study emphasis on the simulation model development and continue with the model testing and policy design and evaluation for better policies of rice production in achieving the 100% rice SSL in Malaysia.

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