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The Analysis of Quality of Paddy Harvest Yield to Support Food Security: A System Thinking Approach (Case Study: East Java)

Mala Rosa Aprillya, Erma Suryani*, Anisa Dzulkarnain

Institut Teknologi Sepuluh Nopember, Jalan Raya ITS, Keputih, Sukolilo, Surabaya, 60111

Abstract

Rice (Oryza Sativa) is a staple food for the people in Indonesia. East Java Province is a province with potential agricultural in Indonesia. East Java has advantages in agriculture and has a role in the national food sector. Population in Indonesia is projected to reach 271.1 million by 2020. East Java's population growth rate from 2010 to 2017 was 0.64% with consumption of 213,783 tons of rice in 2018. Raw materials such as paddy, are perishable materials that require fast and precise handling. When handling is not right it will cause a loss of the results of high quality and quantity, this can be harmful to farmers because it will affect their income. This study uses a system dynamic to build the conceptual model (Causal Loop Diagram) to improving the quality of paddy yields to support food security. The results of study are a model that has some useful information regarding factors that affect the quality paddy. This can be used as decision support by the government for decision making about policies that will be applied to improve the quality of paddy harvest yields for support food security. Further research can be carried out by simulating several scenarios to predict the state of the rice farming system in the future.

Keywords: Decision support; Decision making; Food security; Paddy; Quality of paddy; Rice; System dynamics

1. Introduction

Rice has a large contribution to meet food needs throughout the world. Most of the rice is consumed in developing countries. Most people in Indonesia choose rice as a staple food and the main source of carbohydrates

* Corresponding author. Tel.: +62-812-3135-2063; fax: +62-31-5964-965.
E-mail address: erma.suryani@gmail.com

[1]. As the population increases, this will affect food needs. East Java Province is a province with potential agricultural in Indonesia. East Java has advantages in agriculture and has a role in the national food sector. Most of

the land in East Java has benefited from agricultural and industrial activities. East Java population growth rate from 2010 to 2017 was 0.64% [2] with consumption of 213,783 tons of rice in 2018 [3]. Therefore, it requires a large amount of food supply with better quality [4]. Raw materials such as paddy, are perishable materials that require fast and precise handling. When handling is not right it will cause a loss of the results of high quality and quantity, this can be harmful to farmers because it will affect their income [5]. Rice quality is a very important in the transaction because it will determine the price level and the profit received. The current problems in the food distribution system are still fragmented without vertical coordination in the supply chain from upstream to downstream. Logistics facilities and post-harvest facilities and processing are still limited so the flow of goods is not smooth and product quality often deteriorates. Fulfillment of rice supply is a problem that is complex system implicate various components, elements or elements in it that are integrated [4].

System dynamics models are ways that can be used to represent the relationship between agriculture, system food drivers and their consequences for food security, environment and livelihoods [6]. This study presents a system dynamics approach to understanding the real conditions of a rice farming system. The results of this study are a model of the quality of rice yields based on the real conditions captured and modeled. This paper is organized as follows. Section 1 explains the introduction. Section 2 presents the literature review regarding related studies. Section 3 describes the research methodology. Section 4 presents the results in a causal loop diagram. Finally, in Section 5 explains the conclusion.

2. Literature review

2.1. Quality of paddy

Paddy (Oryza Sativa) is an important food crop for residents in Indonesia. Before becoming rice, paddy has undergone several processes before processing it into several processed food and industrial products. Most paddy producing countries pay more attention to improving the quality of rice. The quality of the paddy harvest yield can be determined from several indicators, such as broken paddy [7, 8]; post-harvest losses [7, 9]; and rendement paddy [9, 10]. Improving the quality of paddy will have a beneficial effect on rice producers and consumers. Improper harvesting and post-harvest handling can cause a decrease in quality [11]. The process of production, post-harvest, milling, and marketing affects the quality of rice. Besides the loss of yield that causes low yields, it also causes the low quality of paddy produced, namely high levels of impurities and hollow paddy and calcifying paddy which results in low of rendement [12]. Losses of yield paddy which is scattered during harvest or post-harvest which can reduce rice production. Results loss due to inaccuracies in threshing can reach more than 5% [7]. This is because the milled yield from year to year has decreased quantitatively from 70% at the end of the 70s to 65% in 1985, 63.2% in 1999, and in 2000 the highest was only 62%, even the reality in the field below 60% [12]. In addition, yield loss in paddy milling also has the potential to reduce rice production due to the low of rendement. Post-harvest handling aims to reduce yield loss, improve quality, save power, use agricultural commodities, expand employment opportunities, and increase value-added production [13]. To overcome this problem, the right strategy is needed and can be applied appropriately.

2.2. Food security

Food security is the ability of the country to ensure the availability, accessibility, and utilization of rice stably for a society [14]. Food security is a problem developing countries often face that. The high production and consumption of rice in Indonesia show that rice commodities not only concern the interests of producers but also the needs of consumers [15]. The dependence of the Indonesian population on rice causes the government to import rice to meet domestic demand for rice. It must consider the availability of rice in Indonesia to achieve food security. It will realize food independence if it achieves food self-sufficiency. If it achieves self-sufficiency and food independence, food security will be strong [4]. To strengthen national food security, the government has issued various policies, such as national rice policies. This policy includes five policy instruments: increased production,

business diversification, price policy, import policy, and rice distribution for poor families. Another problem that arises is that the availability of rice is still uneven. Natural disasters affect the supply of rice and erratic climate change, such as droughts and floods. The availability of rice in Indonesia faces challenges on the production side because the production cycle follows the water cycle while consumption remains relatively unchanged by time [16]. In addition, the conversion rate of agricultural land into non-agricultural land is a common phenomenon that occurs rapidly in Java.

2.3. System dynamics

System dynamics is a simulation methodology introduced by Jay Forrester to understand, visualize and analyze complex dynamic feedback systems [17]. Approach using system dynamics can model nonlinear behavior that is difficult to model with traditional methods such as statistics, and dynamic interactions (feedback) between interconnected factors can be handled easily by doing scenario actions/system changes [6]. The results of the system dynamics approach can be used to help managers and decision makers in order to find policies and decisions that are profitable and can be applied well within a certain period of time. There are five stages in developing a system dynamics model based on Sterman [18]. (1) Problem Articulation is the first step in defining what problems they are trying to add. (2) Formulating a Dynamics Hypothesis must provide an explanation of characterizing the problem in terms of the underlying feedback and structure of the system stock flow. (3) Formulating a Simulation Model on this stage formal models that are fully determined, will be completed with equations, parameters, and initial conditions. (4) The testing phase, the test aims to compare the simulated behavior of the model with the actual behavior of the system. Each equation must be checked for dimensional consistency. (5) Policy Design and Evaluation, at this stage the design of the policy includes making entirely new strategies, structures, and decision rules or recreate the decision-making process by actors in a system.

3. Research methodology

The first step based on Streman [18] is the Articulation of Problems. At the first stage, we held discussions with the expertise of stakeholder. In this case we discussions with the head of field of food crop at the Department of Agriculture, East Java. The head of the food crop sector was chosen as an expert stakeholder because it was preparation of work programs in the field of food crops; preparation of materials and formulation of technical policies, in the field of processing and marketing of food crops; development and facilitation of post-harvest handling and processing of agricultural products and monitoring and evaluating post-harvest handling and processing of agricultural products. This discussion identified the factor and problems faced in the rice farming system in East Java. In addition, we took literature that supports this research from related sources such as books, articles in relevant journals or previous research. We identify variables that contribute to the current problematic situation. System archetype is used as diagnostic tools that provide deeper insight into the underlying structure of system behavior and events that arise. System archetypes consist of various combinations of balancing and reinforcing [19]. In other words, systems archetypes describe behavioral patterns that are of common occurrence in systems. The system archetype is then described in the Causal Loop Diagram as dynamics hypothesis.

Causal Loop Diagram describes the causality in the system. Causal Loop Diagram is very good for capturing hypotheses about the causes of dynamics quickly, raising and capturing models and communicating important feedback that is responsible for a problem. The variable is described by a causal link, indicated by an arrow. Each causal link is given polarity, both positive (+) or negative (-) to show how the dependent variable changes when the independent variable changes. In addition, two types of feedback loops in the system dynamics model are reinforcing (R) and balancing (B) feedback [18].

4. Result

In this section we present the result of factor-factor that influence on rice farming on base on discussion with expertise of stakeholder, boundary chart and relationship of each variable in the causal loop diagram. From the discussion with the expertise of stakeholder, internal and external factors were found that influenced rice

productivity in East Java. Internal factors that influence the increase in productivity include the provision of balanced fertilizers, availability of irrigation water, use of superior seeds. While the factors that reduce land, productivity are pests and diseases. External factors that influence productivity are climate and weather impacts, including temperature and rainfall throughout the year. Model boundary charts and subsystem diagrams show the boundary and architecture system of the model. Model boundary charts for food demand sub-model, paddy land area, paddy productivity sub-model and quality of paddy harvest yield sub-model show in Table 1.

Table 1. Boundary Food Demand.

Sub Model	Endogen Variable	Reference	Exogen Variable	Reference
Food demand	Rice production	[20, 21]	Price rice	[22, 23]
	Rice need per-capita	[1, 24, 25]		
	Population	[26, 27]		
Paddy land area	Expansion Land	[1, 5, 28]	Conversion Land	[1, 5, 29]
Paddy productivity	Cropping Intensity	[30, 31, 32]	Pest	[26, 33]
	Harvest Area	[1]		
	Paddy Varieties	[26]		
	Irrigation	[34]		
	Rainfall	[34, 35]		
	Fertilizer	[36, 37]		
Quality of paddy	Harvesting	[38, 32]	Broken Rice	[8, 9]
	Threshing	[39, 40]	Postharvest Losses	[9, 7]
	Paddy Drying	[39, 40]		
	Rice Milling	[39, 40]		
	Rendement	[9, 41]		

System archetype used as diagnostic tools that represent and classify structure and system behavior. In Fig. 1 describes the archetype system to represent and classify the structure and behavior of the system in this case to illustrate the influence of the quality of paddy yields on paddy production and demand for rice consumption.

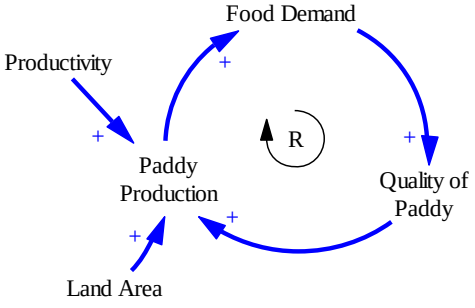

Fig. 1. Archetype System.

The system archetype helps in making detailed details of the Causal Loop Diagram regarding the effect of the quality of rice yields on agricultural production. In this case, there are 4 sub-models to be detailed including food demand, quality of paddy harvest, land area, and paddy productivity. Fig. 2(a) presents a generic structure of food demand problem with limits to growth, consist of a balancing loop (B) and a reinforcing loop (R). The causal loop diagram regarding the demand for rice to meet food needs. Nonlinearities, multiple feedback loops and time delays lead to unexpected system behaviors.

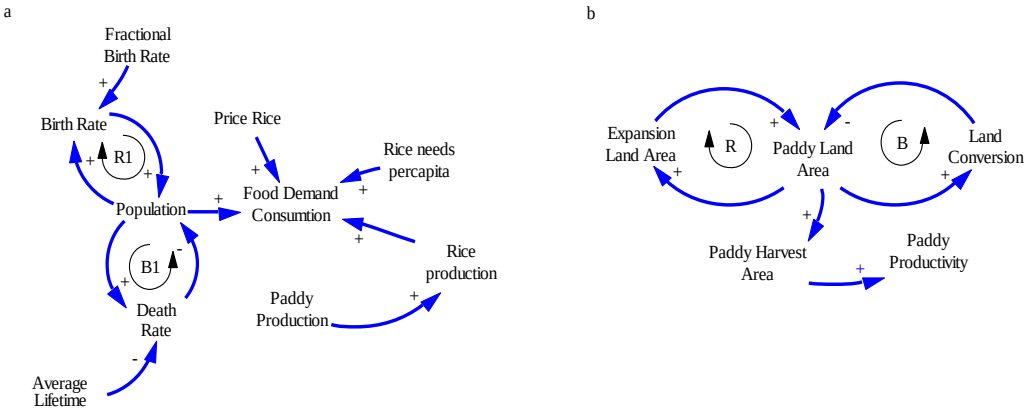

Fig. 2. (a) Food demand sub-model: Limits to growth; (b) Paddy land area sub-model: Limit to growth.

The demand for rice is influenced by paddy production and is influenced by the need for rice per-capita from each person. Population is a significant variable that affects the consumption of rice demand. The population itself is influenced by several factors such as birth rates (R1) and death rates (B1). The effect of rice prices also influences the level of food demand consumption. Several factors that influence rice prices including market information problems, marketing problems, high sale competition and uncertainty in market demand. Therefore, system dynamics archetypes more suitable to describe the interaction among dynamic variable when formulating food policies. Fig. 2b present a generic structure of total paddy land area with limits to growth, consist of a balancing loop (B) and reinforcing loop (R). The causal loop diagram regrading land area of paddy. The paddy land area is affected by the expansion of land area and conversion land area. Along with increasing population and limited land resources. When the land conversion occurs in the paddy area, it will affect the amount of paddy land availability, which will also affect the rice harvest area (B). Paddy land conversion because of changes in land use into housing, industrial and other facilities. However, if there is an additional opening of new land as a paddy field area, it will increase the availability of paddy land area and this will affect the harvest area (R).

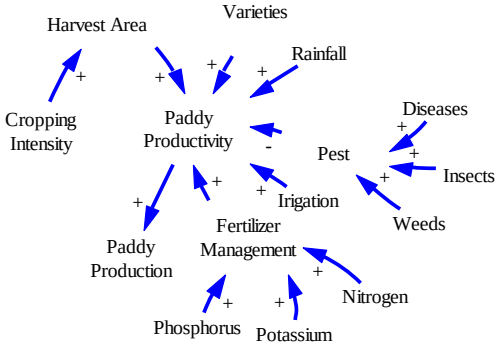

Fig. 3. Paddy productivity sub-model.

Fig. 3 present a generic structure of paddy productivity. Several factors influence paddy productivity. The causal loop diagram about the paddy productivity consist of (1) land area is a percentage of the total land that can be planted, used for permanent crops, and used for permanent areas is a determinant of the production of agricultural commodities; (2) Determination of the seed varieties to be used has a very important role because it determines the superiority of a commodity. The determination of superior seeds is usually resistant to disease and climate change. (3) Increasing cropping intensity by increasing the number of crops planted on the same plot of land can help in increasing paddy productivity; (4) Fertilization to meet nutrient deficiencies needed to produce well. Using

fertilizers is one of the important things in rice cultivation. (5) Irrigation channels are the provision, regulation and disposal of irrigation water to support agriculture. Types of irrigation channels include surface irrigation, swamp irrigation, underground water irrigation, pump irrigation, and irrigation; (6) Pest attacks, the use of pesticides is a way to prevent rice plants from being attacked by pests, controlling pests carried out must take into ecological factors so as not to disturb the natural balance.

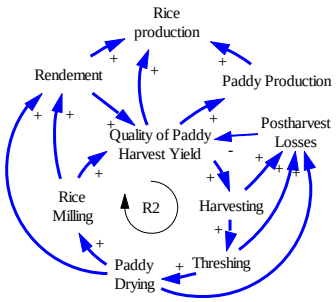

Fig. 4. Quality of paddy harvest sub-model.

Fig. 4 presents some factors that influence the quality of rice yields. Several variables affect the quality of rice yields such as harvest and post-harvest handling. Handling of crops is important to maintain the quality and quantity of grain. Rice harvesting must be done at the right harvest age, using harvesting tools and machines used to harvest rice must be matching type of rice varieties to be harvested. Postharvest handling is threshing, paddy drying, and rice milling (R2). Appropriate post-harvest handling can reduce yield loss, improve quality, save power, expand employment opportunities, and increase value-added production. Fig. 5 presents the overall causal loop diagram of quality of paddy harvest yields on paddy production and demand for rice consumption.

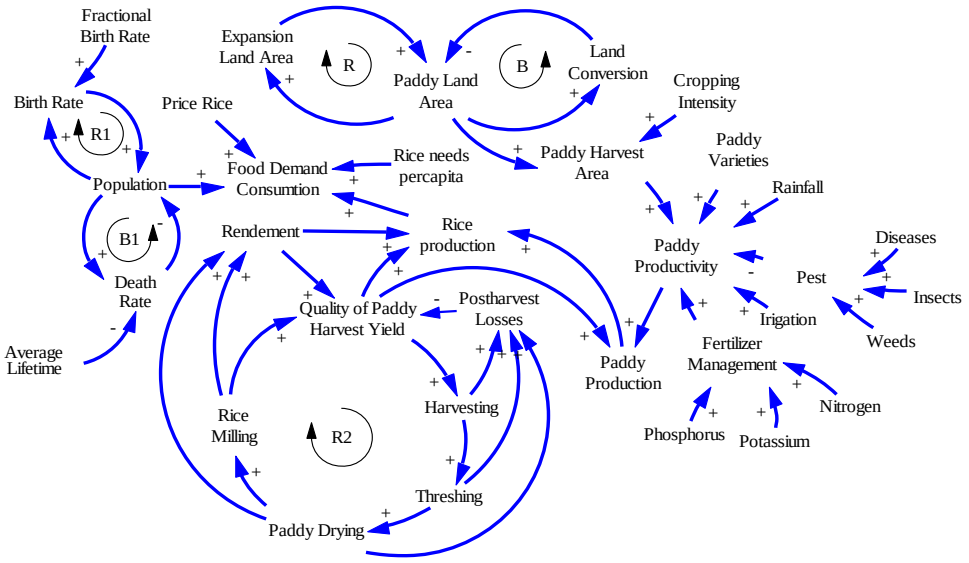

Fig. 5. Full Causal Loop Diagram of Quality of Paddy Harvest Yield.

5. Conclusion

Agricultural systems are systems with complex problems involving various components, elements or elements in them that are mutually integrated. This system is affected by several dynamics of uncertainty, a nonlinear linear relationship between system variables, time lags, and interactive feedback loops. This study presents an analysis in a model that has some useful information regarding factors that influence the quality of paddy harvest yield that

supports food security. System archetype that described in the causal loop diagram is useful for food policy makers. Archetype can be used to describe behavior patterns that commonly occur in agricultural systems, especially in improving the quality of paddy harvest yields. Archetype is used as a diagnostic tool in providing a deeper understanding of where agricultural system behavior and events arise. The basic pattern can be used as a tool to inform the decision markers about food planners to forecast possible future undesirable consequences. From the causal loop diagram generated, further research can be carried out in a series of structural and parameter scenarios to projection the rice farming system in the future and make several policies that need to be implemented to support food security.

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