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Scenario development to create a sustainable price of rice: A system thinking approach

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Abstract

The provision of rice in sufficient quantities and affordable prices is the main objective of agricultural development. However, there are higher margins of inequality for traders in the rice supply chain, making farmers and consumers at a disadvantage. Previous research has overcome this problem by focusing on milling only in the rice milling industry, with the same goal, this study uses a system dynamics to develop a conceptual model with an e-commerce based commerce system scenario. Further research can be carried out by developing the system thinking from this study that can increase profits across all rice supply chain actors.

Keywords: Agricultural productivity; consumption; decision support; rice; supply chain; sustainable price; system dynamics

1. Introduction

Rice is one of the three most important grain crops in the world and has a major contribution to meet the needs of food worldwide [1]. Rice is the main source of carbohydrates in most Asian countries [2]. Most Indonesian people choose rice as their staple food [3][4]. The increasing population growth will affect food needs [5]. The provision of

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food, especially rice, in sufficient quantities and at affordable prices remains the main objective of national agricultural development [6].

Lack of rice supply can lead to social, economic, and political instability in the country. Apart from production aspects that determine availability, distribution aspects and affordable prices are also important components in creating public accessibility to food, especially rice [7]. In the marketing system, the main problem that often arises is that the price of grain received by farmers during the harvest season is almost always low. On the other hand, end consumers often complain about the high price of rice. This situation reflects the asymmetric rice market and the low degree of integration. This means that if the price of rice rises at the consumer level, the increase will not be continued at the farmer level. Farmers are always at a disadvantage through this market mechanism. Conversely, if the price of unhulled rice at the farm level increases, the price of rice paid by consumers will certainly increase. However, if the price of unhulled rice falls at the farm level, the decline will not necessarily lead to a decrease in the price of rice at the consumer level. In this case, the consumer is at a disadvantage. The asymmetric nature of the rice market will be a profitable area for traders. At the same time, both producers (farmers) and consumers are at a disadvantage. Low price transmission rates reflect low market efficiency [8].

The rice industry policy must cover the entire supply chain network, which consists of at least 3 levels, namely: farmers, distributor, and retailers, because it will cause margin inequality which tends to be higher for traders [9]. This problem encourages learning more about the rice supply chain system, the rate of price transmission from one market player to another, and the benefits obtained by various market players in the rice supply chain.

Previous research stated that cutting the rice supply chain from farmers to consumers can increase the price of unhulled rice at the farm level and reduce the price of rice at the consumer level. This supply chain cut is carried out by milling grain only in the grain milling industry [10]. With the same goal, this research will apply a scenario of an e-commerce based commerce system. The scope of this research includes 3 sub-models of the rice supply chain, namely: at the farmer, distributor, and retailer levels. It is important that the supply chain that reflects the performance of the rice production and distribution system is reviewed and disclosed in this article.

System dynamics modeling is a method that can be used to represent the relationships between market actors in the rice supply chain. This study presents a system dynamics approach to understand the real conditions of the rice supply chain. The result of this study is in the form of rice supply chain modeling based on the actual conditions obtained and modeled. This paper is structured as follows. Section 1 provides an introduction. Section 2 provides a literature review of the related studies. Section 3 describes the research methodology. Section 4 presents the results in the causal loop diagram. And finally, Section 5 explains the conclusions.

2. Literature review

2.1. Rice supply chain

The supply chain is a collection of market and business actors involved in a series of business processes in a supply chain [11]. Supply chain network flow is a series of marketing agencies through which products are passed in their distribution from producers to consumers [12]. From the flow of rice supply chain network in Indonesia, it consists of two intermediaries, namely: distributors who collect agricultural products from farmers and then market them back to other retailers who will sell them to the final consumer.

The rice marketing system is inseparable from marketing agencies that take part in marketing activities. Each of the marketing agencies has an important role in rice marketing [12].

- Farmers: rice producers who then sell rice to collectors, retailers or choose to sell themselves to earn their income.
- Distributors: traders who collect farmer's products which are then resold to retailers.
- Retailer: traders who buy rice from collectors or directly from farmers and then sell it back at a higher price.
- Consumers: people who buy rice from retailers, or directly from farmers who act as sellers of their products.

2.2. System dynamics

System dynamics are a method for increasing understanding in complex systems [13]. Approaches using system dynamics can model non-linear behavior as well as dynamic interactions (feedback) between interconnected factors

that can be handled easily by carrying out action scenarios or system changes [14]. Until recently, the application of system dynamics methods has continued to develop since its use in the social and physical sciences. There are 5 stages in developing a system dynamics model [13], namely: *problem articulation, dynamics hypothesis, formulation, testing,* and *policy formulation.*

3. Research methodology

Problems regarding the rice supply chain system and the rate of price transmission from one market player to another do not reflect market efficiency because there is an imbalance of margins which tends to be higher for traders and causes producers (farmers) and consumers to be at a disadvantage. Among many methodologies available for dealing with this type of problem, system dynamics modeling is used because of its ability to explicitly address problems with systemic and dynamic drivers, allowing for increased understanding of emerging problems and behaviors [15][13]. The system dynamics simulation approach is considered suitable because it is based on feedback in each part of the system that affects other parts [17].

According to Sterman [13], the first stage in the system dynamics approach is the articulation problem. This stage is carried out by defining the problem to be solved using a system dynamics model and the related variables therein. At this stage, a literature study is carried out to support research from various sources such as books, articles in journals or previous research, government websites such as the Ministry of Trade, and mass media sites to obtain information about the current rice supply chain. Literature data are used to find variables that will be associated with the interplay of problem behaviors in the rice supply chain system.

The next stage according to Sterman [13] is the *dynamics hypothesis*. At this stage, the mapping of causal structures is carried out based on literature studies using boundary adequacy and causal loop diagrams by performing simulations, dynamics hypotheses will be taken from looking at the structure of the relationship between variables. The variables are associated with a causal relationship, indicated by arrows. Each causal relationship is assigned a polarity, either positive (+) or negative (-) to show how the dependent variable changes when the independent variable changes. Besides, there are also two types of feedback loops in the system dynamics model, namely, gain feedback (R) and balance feedback (B) [13].

The basic model of the rice supply chain when described in systems thinking is shown in Fig. 1. Rice production has an impact on farmer sales, farmer sales affect distributor sales, distributor sales affect retailer sales, then retailer sales affect the adequacy of consumer demand, consumer demand will push the rice production.

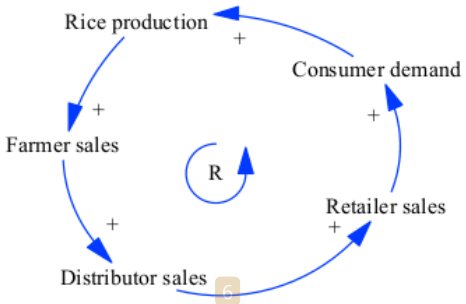

Fig. 1. Basic model of the rice supply chain.

4. Result

This section presents the results of internal and external factors affecting the rice supply chain, including the rate of price transmission from one market player to another and the benefits obtained by various market players in the rice supply chain. The results of these internal and external factors are based on previous literature studies, as well as the relationship of each variable in the causal diagram. The results of literature studies from books, articles in journals or previous research, government websites such as the Ministry of Trade, and mass media sites show internal and external factors that influence the rice supply chain. The following is the projection of the results of this study:

4.1. Boundary adequacy

Internal and external factors, both influencing variables and supporting variables that influence each other in making a system dynamics model of the rice supply chain, are listed in Boundary Adequacy as seen in Table 1.

Table 1. Boundary adequacy of the rice supply chain.

Sub Model	Endogenous	Exogenous	Reference
Rice production	• Paddy production • Rendement • Paddy harvest area • Paddy productivity • Rice production		[18], [4], [19], [20], [21], [22], [3], [1]
Profit of farmer, distributor, and retailer	• Consumer demand of rice • Revenue • Profit margin • Market expense • Rice for sale	• Rice price • Inflation effect	[3], [1], [23], [24], [25], [26], [27], [28], [29], [30], [11], [31]
Rice demand	• Consumption per capita • Population • Indirect rice consumption		[32], [22], [33], [34], [35], [36]

4.2. Submodel of rice production and farmers profit

Fig. 2 presents the general structure of the rice production problem and the profits earned by farmers. The amount of rice production is influenced by the amount of rice production and the yield value. Meanwhile, the amount of rice production is the result of multiplying the total rice productivity with the rice harvested area. Rice harvested area is influenced by land expansion (R1) and land conversion (B1). The land expansion will increase the availability of paddy land. Meanwhile, the land conversion will reduce the amount of rice land availability. The wider the paddy land, the greater the intensity of land conversion. The harvested area affects the total amount of rice production.

There are several factors, both internal and external, that affect the amount of rice productivity. The variables that affect the amount of rice productivity consist of: (1) the use of seed varieties that has a considerable influence on rice productivity; (2) the use of fertilizers to meet nutrient deficiencies in the soil that is important in increasing rice productivity; (3) irrigation channels that function to support irrigation in rice cultivation; (4) manpower that is the labor needed in the cultivation process covering almost the entire production process; (5) rainfall which affects the amount of production and quality of results; (6) agricultural machinery equipment which is a sophisticated agricultural aid that has a high level of productivity; and (7) pest attack which will reduce rice productivity.

The amount of rice production will affect farmer sales. Rice production will also affect the price of rice at farmer level. The greater the rice production, the lower the price of rice at the farm level. Apart from being influenced by the amount of rice production, the price of rice at the farm level is also influenced by distributor demand and inflation. Farmer's profits are influenced by the farmer's income which is reduced by the costs incurred by the farmers in the form of variable costs and fixed costs. Meanwhile, farmer's income is influenced by the price of rice at the farm level and the number of sales made by farmers.

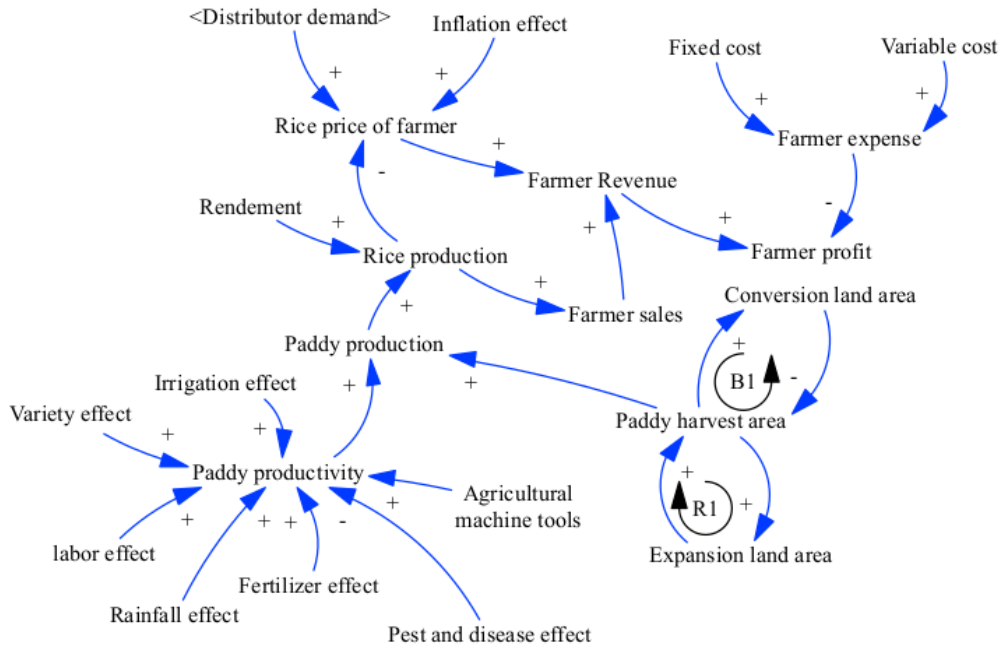

Fig. 2. Rice production and farmer's profit.

4.3. Submodel of distributor profit, rice demand and retailer profit

Fig. 3 presents the general structure of the distributor profit, rice demand, and retailer profit. The amount of rice sales from farmers affects the sales that will be made by the distributor and the costs incurred by the distributors to buy rice from these farmers. Costs incurred by distributors are calculated from the number of rice sales from farmers multiplied by the price of rice at the farmer level. In addition, sales to be made by distributors are also influenced by distributor requests which are calculated from the amount of rice to be sold to retailers. The distributor's profit is influenced by the distributor's income subtracted by the costs incurred by the distributor to buy rice from farmers. Meanwhile, the distributor's income is influenced by the price of rice at the distributor level and the number of sales made by the distributor. The price of rice at the distributor level is determined by the price of rice at the farmer level and is influenced by retailer demand and the profit margin at the distributor level.

Consumer demand for rice is calculated based on the calculation of the per capita consumption of rice multiplied by the total population as direct demand plus indirect rice demand. The population itself is affected by the birth rate (R2) and the death rate (B2). The greater the consumption per capita and the population shows a positive polarity (+) which means increasing the demand for rice directly. Consumer demand for rice affects the size of retailer demand and the price of rice at the retailer level.

The amount of rice that the distributor sells to the retailer affects the sales the retailer will make and the costs incurred by the retailer to buy rice from the distributor. Costs incurred by retailers are calculated from the amount of rice that the distributor sells to retailers multiplied by the price of rice at the distributor level. In addition, sales to be made by retailers are also influenced by retailer demand obtained from the total consumer demand for rice. The retailer's profit is influenced by the retailer's income subtracted by the costs incurred by the retailer to buy rice from the distributor. Meanwhile, retailer's income is influenced by the price of rice at the retailer level and the number of sales made by the retailer. The price of rice at the retailer level is determined by the price of rice at the distributor level and is influenced by consumer demand for rice and profit margins at the retailer level.

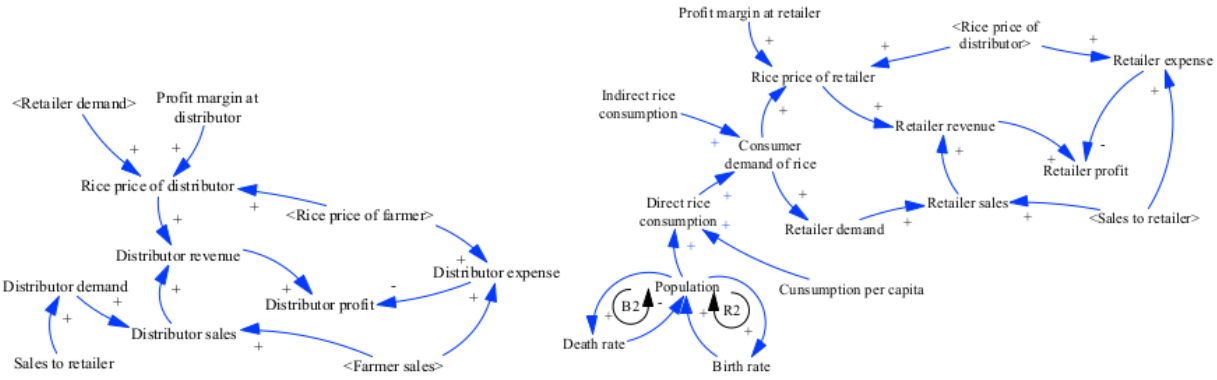

Fig. 3. Submodel of distributor profit, rice demand and retailer profit.

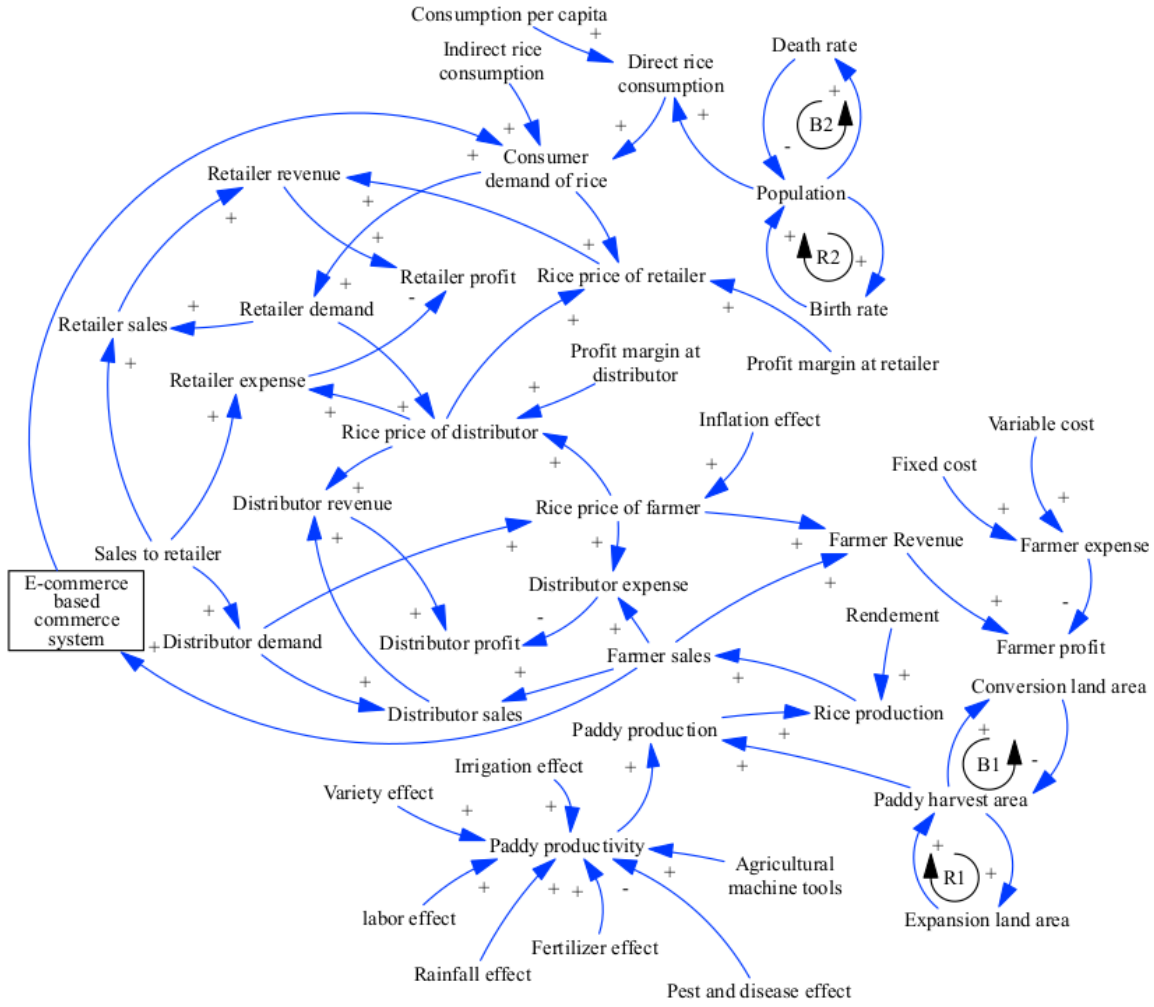

Fig. 4. CLD rice production and distribution.

After identifying variables that influence each other as depicted in a causal loop diagram for each supply chain actors, namely: farmers, distributors, and retailers, a causal loop diagram, which is a combination of the three causal loop diagrams for each of the supply chain actors, is made. Fig. 4 presents a causal loop diagram of the overall relationship between the rice supply chain variables which reflect the distribution or marketing performance of rice to the end consumers including rice production and farmers' profit, distributors' profit, as well as rice demand and retailers' profit. The profit for each supply chain actor includes the rate of price transmission from one supply chain actor to another.

Fig. 4 shows that the advantages of each market actor in the supply chain are interrelated. Each profit is made indirectly by the various variables previously identified. The costs incurred for each supply chain actor are examined by the price of rice at the level of the previous supply chain actor and the price purchased from the previous supply chain actor. Meanwhile, the price of rice at the level of each supply chain actor is determined from the price of rice at the previous supply chain actor level, demand from consumers or supply chain actors thereafter, and the amount of profit margin of each supply chain actor. The scenario that can be done to increase the profits of rice supply chain is to implement an e-commerce based commerce system. This scenario will shorten the supply chain from farmers directly to consumers, thereby increasing the price of grain at the farm level and lowering the price of rice at the consumer level.

5. Conclusion

The rice supply chain system is a system with complex problems involving various interrelated variables. This system is influenced by several variables which are interconnected linearly or nonlinearly with interactive feedback loops. The formulation of a conceptual model (causal loop diagram) with a system dynamics perspective requires in-depth understanding and information about the current rice supply chain system; thus, the model built can represent current conditions. The finding of this study is the scenario development of an e-commerce based commerce system described in system thinking, this can increase the price of grain at the farm level and reduce the price of rice at the consumer level. The system thinking described in the conceptual model (causal loop diagram) can be used by the government and stakeholders for decision making in formulating strategies and policies related to the rice supply chain system that focuses on controlling the rate of price transmission from one market player to another; thus, inequality of margins at all levels of the supply chain will not happen. From the causal loop diagram, further research can be carried out with further development of systems thinking and its scenarios to predict the future of sustainable rice price that can increase profits across all actors in the rice supply chain.

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