

A Systems Approach to Study the Malaysian Pepper Industry

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Abstract: Malaysian pepper industry is facing supply constraints which may affect its future. The system dynamics model provides a framework for understanding the dynamics and feedback structure of the Malaysian pepper supply and demand systems. The choice was made based on the ability of this model in capturing complexity and feedback relationship. The pepper model integrates key elements such as area, production, inventory, price, profitability and demand. The research question is: What are the likely future trends of pepper supply and demand under the different price conditions? The situation requires one to seek a methodology that could explain the complexity of the system and to establish an insight on the interrelation of the key variables. Simulation results indicate that the pepper area is expected to increase rapidly over the next decades, however production is expected to grow slowly because of the low productivity and price volatility.

Keywords: Demand, Pepper, Price, System Dynamics, Supply

Introduction

Pepper was first introduced into Malaysia in 1583 and became the fourth major agricultural crop after palm oil, rubber and cocoa. Malaysia was the dominant pepper producing country in the world until 1980 and now is the fourth largest pepper producing country after Brazil, India and Indonesia (International Pepper Community, 2015). The area planted decreased from 13,849 ha in 1980 to 13,000 ha in 2013 with an average yearly decrease rate of 0.002% (Fig. 1). The change in pepper cultivated area was mainly due to changes in pepper price. Higher prices will normally increase areas under cultivation, resulting in more rounds of harvest and subsequently increase pepper production (Arshad *et al.*, 2007). The pepper price is the significant determinant of the total revenue of Malaysia particularly for the state of Sarawak and pepper farmers' lives as pepper farming is the only source of livelihood for majority of the pepper farmers in state (Kiong *et al.*, 2013).

Total production of the pepper decreased from 31,460 ton in 1980 to 21,000 ton in 2013 by 0.33% (Fig. 2). Roughly 90% of pepper production is destined for export markets. The target markets are China and Middle East Japan, Australia, Europe and South Africa. The pepper production pattern in 1980-

2012 indicates an increasing trend albeit at a very slow growth rate and cyclical behavior like other agricultural commodities in Malaysia. The future of pepper is challenged by fundamentals such as competition for factors (land, labor and capital) for other crops and non-agricultural uses. On the other hand, the losses of productivity due to the major diseases such as Phytophthora foot root, black berry velvet blight and damaging pests remain a critical problem (Arshad *et al.*, 2007).

In short, the industry is facing supply constraints which may affect its future. In the world market, the prospect is relatively good in view of the increase in demand particularly from the food processing sector.

The Malaysian government has taken a number of initiatives to ensure future growth of the sector despite the challenges. These include: To regulate, promote and improve the marketing of pepper and value-added pepper products (Arshad *et al.*, 2007). This study attempts to examine the dynamics of supply and demand and their impact on the behavior and performance of the industry. Based on this analysis, attempts are made to simulate the future of the industry. The general objective of the study is to examine the impact of changes in Malaysian pepper price on pepper industry.

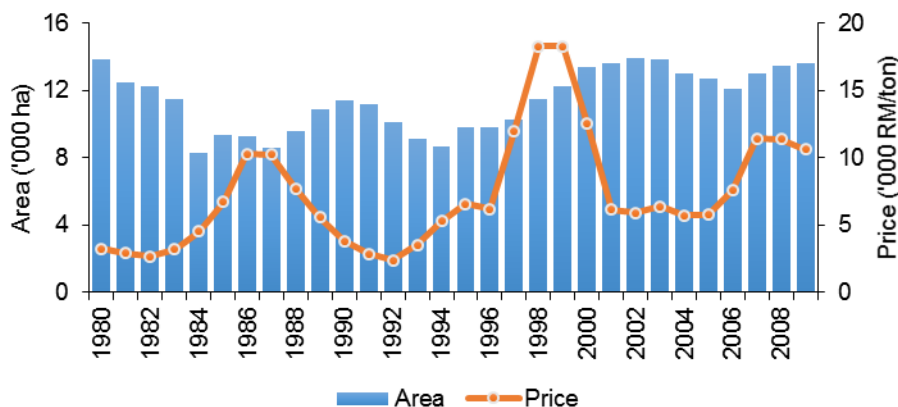


Fig. 1. Pepper Planted Area, Production and Price in Malaysia (1980-2009) Source: Malaysian Pepper Board 1980-2009

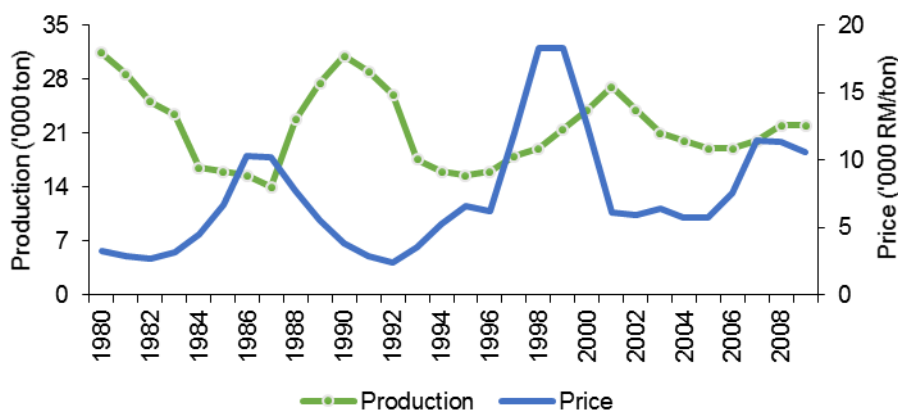


Fig. 2. Pepper Production and Price in Malaysia (1980-2009) Source: Malaysian Pepper Board 1980-2009

Methodology

Among the methodologies available, system dynamics approach is highly suitable to examine the circular causality phenomenon between variables under a complex system (Sterman, 2000). The method is relevant to solve complex issues within a system and to identify the behavior of the system during the specific period. Overall dynamic trends such as fluctuation, decrease, rise, fall or oscillations are more critical than numerical value of system variables indicated (Meadows, 1979). In system dynamics, model building process consists of: Problem articulation, dynamic hypothesis, formulation, testing and policy formulation and evaluation (Sterman, 2000).

In the problem articulation stage, problem statement needs to be clarified. All information about the behavior of the problem is important including historical behavior of the key concepts and variables. Collected data can be utilized as a reference mode to investigate the problem and to shape the dynamic

hypothesis. A dynamic hypothesis is developed as soon as the problem statement has been identified and described over a specific time period. Consequently, a causal mapping is developed based on the hypothesis, key variables, reference and other accessible data using boundary diagrams, subsystem diagrams, causal loop diagrams and other helpful tools. Boundary and subsystem diagrams show the structure and boundaries of the model, however they do not show how the variables are interrelated. The links among variables are done by using arrows according to their effect to each other. Thus, causal loop diagrams are helpful tool for mapping feedback structure (Sterman, 2000).

Formulation stage concerns with the equations used in the model and converting causal loop diagrams into a stock and flow diagram. These processes are usually done by using specific software like a Stella, Vensim and others. Once conversion from causal loop diagram to stock and flow is finished, equations among variables are set. A stock is a term refers to variables that accumulates or depletes over time. Inflow or

outflow is the indicator of change in a stock. The simulation of the model begins as the equations are written and comparison of the simulation results of the model to the real behavior of the system are done. Besides replication of historical data, dimensional consistency check must be conducted to avoid errors. As soon as model replicates same structure behavior with the actual data, model must be checked for sensitivity and extreme conditions test. Once certainty in the structure and behavior of the model is obtained, model can be utilized to design and evaluate policies.

Dynamic Hypothesis

In this study, it is hypothesized that endogenous feedback structure of a conceptual model should be able to produce the underlying behavior of the system.

Causal Loop Diagrams

Sterman (2000) presents a generic structure for commodity markets, adapted from Meadows (1970) who developed initial feedback structure for commodity cycles and applied it to livestock. Generic commodity market model involves: Supply, demand, price, profitability, cost and other key variables. Generic structure could be applied in developing other commodity models. Arshad (2015) adopted the structure to study boom and bust of cocoa production systems in Malaysia. Ford (2011) studied the cyclical behavior in the production and prices of hogs using the same technique. The same system structure is utilized in this study.

There are five balancing loops (B1, B2, B3, B4 and B5) in the pepper supply and demand system

dynamics model (Fig. 3). The balancing loops B1 and B2 represent the production and price loops respectively. They comprise eight variables. Balancing loop B1 includes pepper area, production, production cost, expected profitability and new cultivation whereas B2 includes area, production, inventory, indicated price, expected price, expected profitability and new cultivation. The relationships between the variables follow the principles of an economic theory. As the price of pepper increases (decreases) producers expected profitability will increase (decrease), thus farmers tend to expand (reduce) the pepper area. If the area increases (decreases), production and inventory level will also increase (decrease). The balancing loops labeled B3 and B4 depict the local demand and export demand respectively. In balancing loop B3, the expected price and local consumption has a negative relationship. Increase (decrease) in local consumption leads to an increase (decrease) in total demand which in turn decreases (increases) the inventory.

In the export demand loop, export price is function of domestic price and F.O.B cost. If the export price increases (decreases), export demand will decrease (increase) which in turn increases (decreases) the total demand.

The balancing loop B5 depicts the structure of import and it includes demand and inventory. As the demand for the pepper increases (decreases), the inventory level will decrease (increase). To cover the shortage, more pepper is imported to the country. It is important to note that delays are part of the structure.

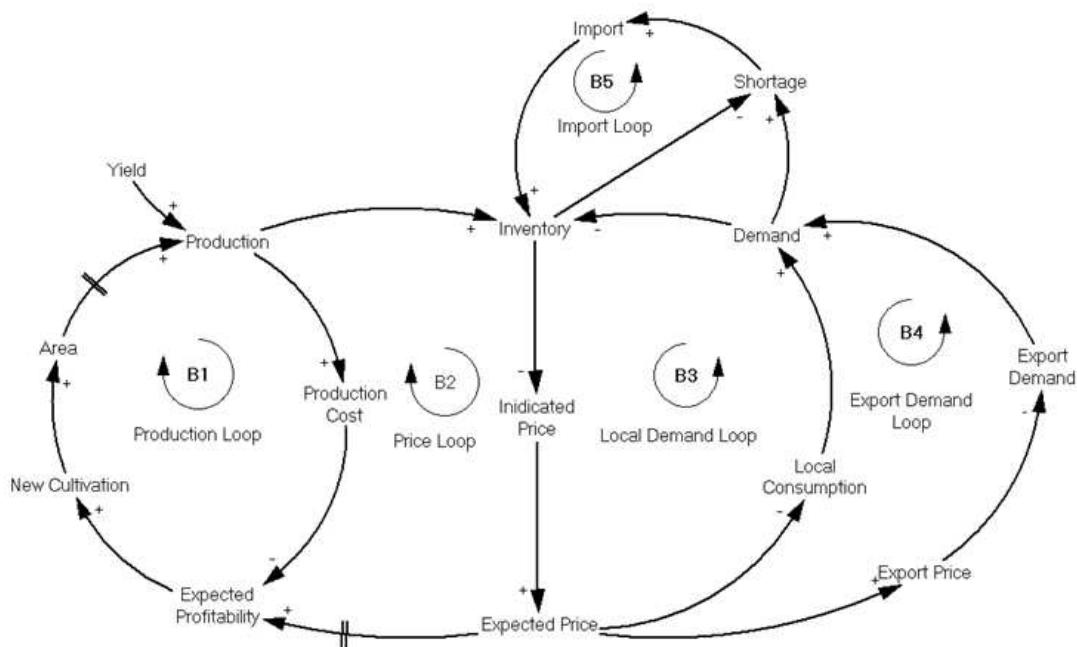


Fig. 3. The causal loop diagram of the Malaysian pepper supply and demand

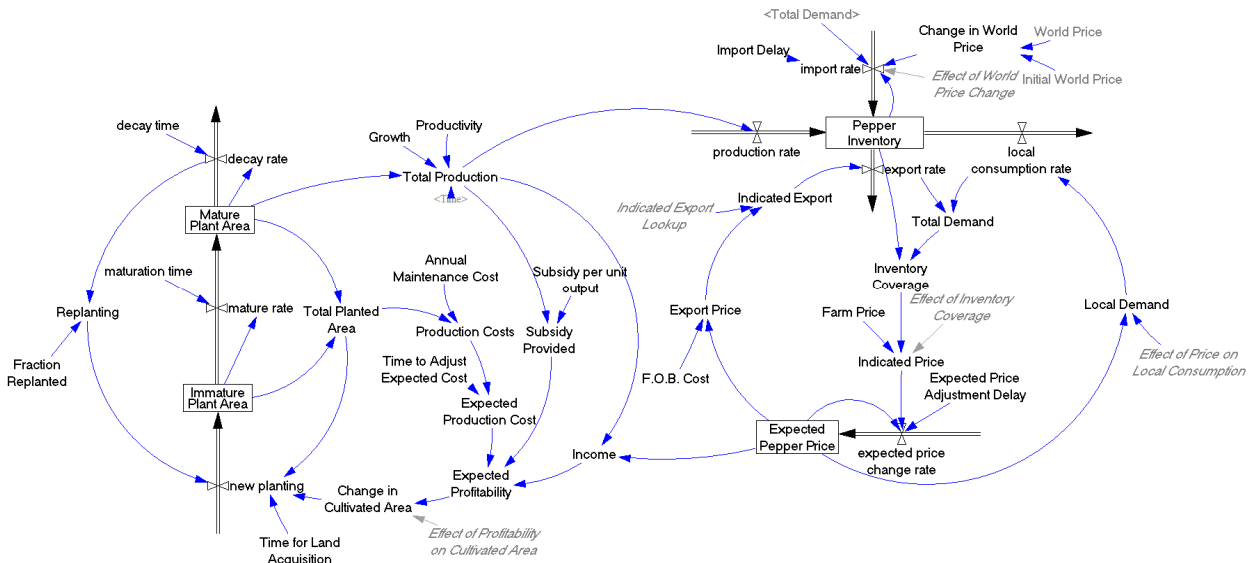


Fig. 4. The full stock and flow diagram of the Malaysian pepper supply and demand

Stock and Flow Diagram

In this step, the causal loop diagram is transformed into a stock and flow diagram and equations are set between variables using modeling tool Vensim DSS (Repenning and Sterman, 2003), so that one can further examine the dynamics and run different tests. The model structure (Fig. 4) is adopted from generic structure of commodity market by Meadows (1970) and Sterman (2000).

There are two stocks in the pepper area section which are immature and mature plant areas. Immature plant area represents the all immature pepper areas in the country. It is noteworthy to mention that 90% of the total pepper planted area of the country located in Sarawak state (Rahim et al., 2012). New planting rate augments the immature plant area and is the sum of the replanting and change in the cultivated area. The relationship is captured in Equation 1:

$$\text{New planting rate} = \left(\frac{\text{Replanting} + \text{Change in Cultivated Area}}{\text{Time for Land Acquisition}} \right) [\text{ha / year}]$$

Immature plant requires 3 years to become productive and in the model immature plant area stock is diminished by mature rate which is immature plant area divided by maturation delay:

$$\text{Immature Plant Area} = \int_0^t [\text{new planting rate}(t) - \text{mature rate}(t)]dt + \text{Immature Plant Area}(t_0) [\text{ha}]$$

Mature rate

$$= \text{Immature Plant Area} / \text{maturation delay} [\text{ha / year}]$$

Mature plant area is augmented by the maturation rate and is diminished by the decay rate. Decay period represents the economic cycle of the crop which is 7 years after the immature crop became mature:

$$\text{Mature Plant Area} = \int_0^t [\text{mature rate}(t) - \text{decay rate}(t)]dt [\text{ha}]$$

$$\text{Decay rate} = \text{Mature Plant Area} / \text{decay time} [\text{ha / year}]$$

The stock variable, pepper inventory is increased by the production and import rate, however it is decreased by the local consumption and export rate. This is shown in Equation 2:

$$\text{Pepper Inventory} = \int_0^t [\text{production rate}(t) + \text{import rate}(t) - \text{local consumption rate}(t) - \text{export rate}(t)]dt + \text{Pepper Inventory}(t_0)$$

The production rate augments the inventory and is the result of the mature plant area multiplied by the pepper productivity per ha:

$$\text{Production rate} = \text{Productivity} \times \text{Mature Plant Area} [\text{ton / year}]$$

The import rate is calculated as the pepper inventory subtracted by the total demand for the pepper and multiplied by the effect of the world price change:

$$\text{Import rate} = (\text{Pepper Inventory} - \text{Total Demand}) \times \text{Effect of World Price Change} [\text{ton / year}]$$

The inventory coverage (the ratio of the existing inventory level to the consumption) determines the pepper price movements. The indicated price is estimated multiplying the initial farm price by the effect of the inventory coverage. When the relative inventory coverage is low, the pepper price will reach its maximum and when the inventory coverage increases the price will decrease. The price change influences the per capita consumption. The pepper price expectation in the model is estimated as follows:

$$\begin{aligned} &\text{Expected Pepper Price} \\ &= \int_{t_0}^t \text{expected price change rate}(t) [\text{RM / ton}] \\ &+ \text{Expected Pepper Price}(t_0) \end{aligned}$$

The pepper price expectation is linked to the expected profitability through an income. The change in the cultivated area is the result of farmer upward

(downward) adjustments as a response to profitability, by the expansion (reduction) of area when conditions are beneficial (unfavorable):

$$\begin{aligned} \text{Expected Profitability} = & \\ &(\text{Subsidy Provided} + \text{Income} - \text{Expected Production Cost}) \\ &/ \text{Expected Production Cost} [\text{dimensionless}] \end{aligned}$$

Results

Model Validity and Testing

Model values were estimated from the primary and secondary data collected from different sources. The validation procedures such as: Boundary adequacy check, dimensional consistency check, parameter check, extreme conditions, behaviour reproduction and behaviour sensitivity check were conducted to establish confidence in the model. In the behaviour validity tests, model trend pattern is critical rather than on point prediction (Barlas, 1996).

Figure 5 shows the comparisons of simulated behaviors of pepper plantation area, production, demand and price with the historical data. The reference and simulated behaviors agree adequately and model predictions represent reality.

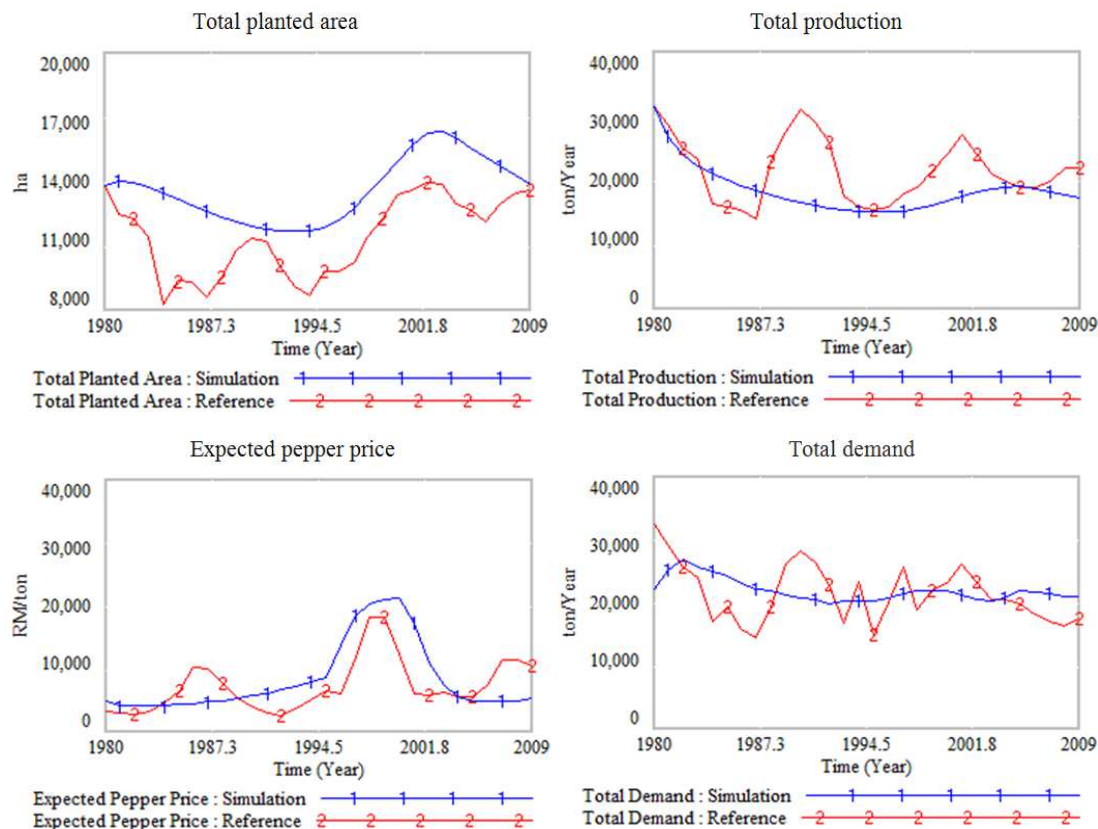


Fig. 5. Simulated and historical patterns of pepper production systems in Malaysia

Discussion

Scenario Analysis

Scenario analysis involves parameter changes to generate different exogenous situations or administrative decisions keeping the model structure unchanged. The initial simulation run is called as “business as usual” as it assumes that people keep to make decisions in the future as they have in the past. The following scenarios assume that price of the pepper was decreased by 50 and 25% which could happen when the supply exceeds the demand and another two scenarios are increase of pepper price by 25 and 50% and these occur when the demand is higher than the supply (Fig. 6). The scenarios run period is 15 years starting from 2015.

The pepper price is the main driver of total planted area and total demand growth. The pepper planted area is expected to grow under the all scenarios. About 50% decline in pepper price is expected to give better result rather than other scenarios in the case of the area. Under the scenario 5, the area increases slowly compare to other scenarios until 2023, albeit it indicates the highest growth onwards.

Obviously, the observed production patterns differ from one another, thus must have a significant effect on the supply, demand and price. Under the scenario 5, production is expected to show the highest increase in the long term (Fig. 7). This pattern is in line with the hypothesis we have made earlier.

Demand is expected to change slightly under the five scenarios (Fig. 8). The demand is expected to increase by 0.014% under the scenario 1 in 2015-2030. Under the scenario 5, demand shows dominant increase rate by 8% in 2015-2030. To summarize the findings, pepper area, production and demand is expected to increase under the scenario 1 in the short term however to benefit in the long term, the scenario 5 is expected to give better results.

Sensitivity Analysis

Sensitivity of price and area behavior was tested to adjustments in price adjustment delay. Figure 9 illustrates that the expected pepper price has a decline potential once growth in price adjustment delay augments and the expected pepper price eventually collapse at maximum adjustment delay growth.

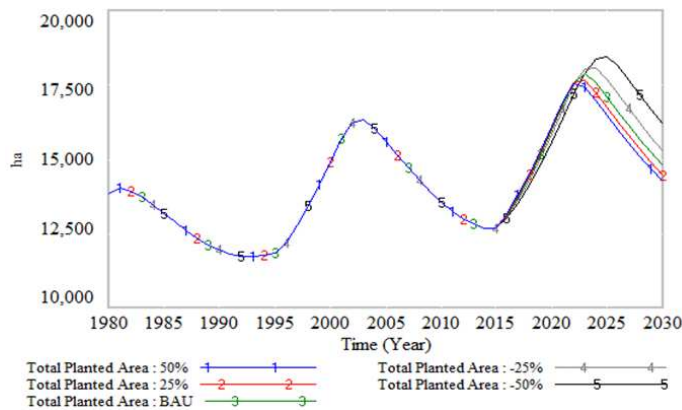


Fig. 6. Area change pattern under the five scenarios

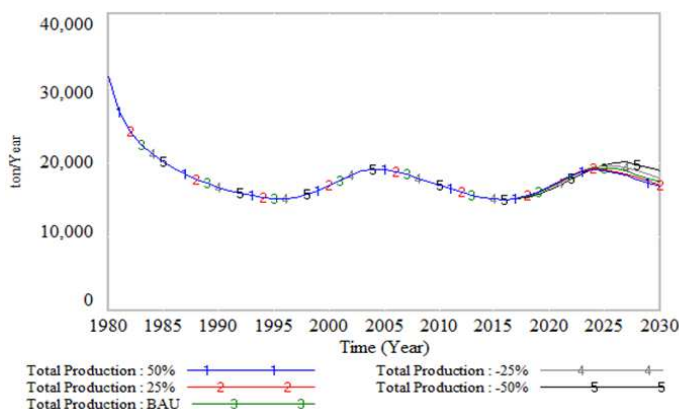
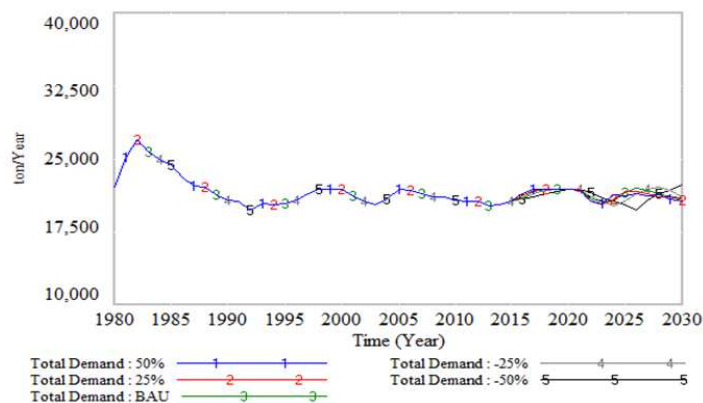


Fig. 7. Production change pattern under the five scenarios



Scenario	Price Change	Total Change
1	50 %	0.014 %
2	25 %	0.3 %
3	BAU	1.25 %
4	-25 %	1.8 %
5	-50 %	8 %

Fig. 8. Demand change pattern under the five scenarios

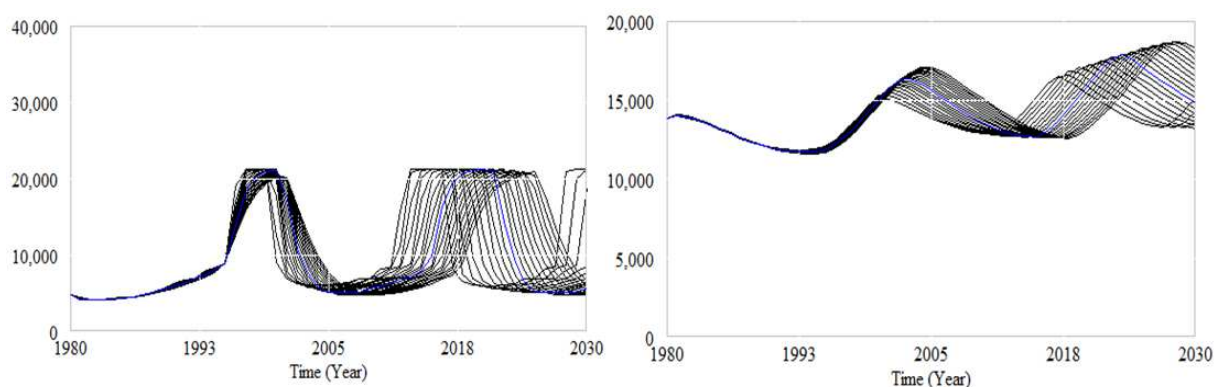


Fig. 9. Test of expected pepper price and area to changes in price adjustment delay

However, area has a growth potential once price adjustment delay increases. These behaviors are in line with economic theories.

Conclusion

In this research, the formulation of a system dynamics model is explained to simulate the behavior of the Malaysian pepper production system over the next decades. Considerable insights have been obtained that lead to a reasonable conclusions. The simulation results show that market equilibrium can be obtained through production capacity growth on supply side in parallel with adjustments on demand side. The pepper area is expected to increase rapidly over the next decades, however production is expected to grow slowly because of the low productivity and price volatility. Researchers could involve qualitative and structural model extensions. For example, the pepper productivity sub-section can be incorporated on the supply side.

Author's Contributions

Ibragimov Abdulla: Performed the experiments, analyzed the data and gave the conclusions, discussed

the results, implications and commented on the manuscript at all stages.

Fatimah Mohamed Arshad: As the advisor, she designed the research plan and organized the study.

Muhammad Tasrif: Contributed in development of the conceptual framework and the stock and flow diagram.

Bach N.L.: Contributed in development of the conceptual framework and the stock and flow diagram.

Sahra Mohammadi: Carried out the validation and statistical tests.

Ethics

The authors have no conflicts of interest in the development and publication of this research.

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