Conceptualization of system dynamic for patchouli oil agroindustry development

by Dina Rahmayanti

Received: 13 March 2019 | Revised: 20 June 2019 | Accepted: 20 June 2019
DOI: 10.1002/bsd2.85

RESEARCH ARTICLE

WILEY Business Strategy and Development

Conceptualization of system dynamic for patchouli oil agroindustry development

Dina Rahmayanti[1] | Rika Ampuh Hadiguna[2] | Santosa Santosa[3] | Novizar Nazir[4]

[1] Department of Industrial Engineering, Faculty of Engineering, Department of Agricultural Science, Faculty of Agricultural, Universitas Andalas, Padang, Indonesia

[2] Department of Industrial Engineering, Faculty of Engineering, Universitas Andalas, Padang, Indonesia

[3] Department of Agricultural Engineering, Faculty of Agricultural Technology, Universitas Andalas, Padang, Indonesia

[4] Department of Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Andalas, Padang, Indonesia

Correspondence
Dina Rahmayanti, Department of Industrial Engineering, Faculty of Engineering, Department of Agricultural Science, Faculty of Agricultural, Universitas Andalas, Padang [illegible]63, Indonesia.
Email: rahmayantidina@gmail.com

Abstract

Patchouli oil industry is one of the sectors that should be developed in Indonesia because Indonesia supplies around 90% patchouli oil in the world. This study aims to identify the data required for making agroindustry development decisions using system dynamic. This research was designing the stock flow diagrams (SFD) of patchouli oil from the plantation to the exporter. There are four types of SFD patchouli oil agroindustry, namely, plantation section, farmer section, collector section, and exporter section. The results of the study can identify the data needed as input for the dynamic system model. Input data must be determined first to run the model. Input data for each stage of SFD must be available if the government wants to do the development of patchouli oil agroindustry using a dynamic system model.

KEYWORDS

decision support system, patchouli oil agroindustry, stock flow diagram, strategy, systems dynamic

1 | INTRODUCTION

Patchouli oil industry is one of the sectors that should be developed in Indonesia because it has many advantages (Junaedi & Hidayat, 2010). Regarding raw materials, it is quite available because the geographical of Indonesia is suitable for patchouli plants. Regarding processing technology that is relatively simple, processing can be done traditionally using drums heated with wood fuel. Patchouli oil industry absorbs a lot of labor. It has a clear market and also high demand.

Indonesia supplies around 90% patchouli oil in the world or 1,600 tons per year (Directorate General of Plantations, 2016). But patchouli oil agroindustry in Indonesia is not well developed. Indonesia's patchouli production in recent years has tended to be unstable and declining (Central Statistics Agency, 2015). On the basis of potential and current conditions of patchouli oil agroindustry, the role of the government needs to develop patchouli oil agroindustry. The government needs to take many considerations for making decisions on the development of patchouli oil agroindustry. In the case of patchouli oil agroindustry, there is a tendency for a situation that often changes every time, for example, uncertain price changes that affect the amount of patchouli oil produced. Price is not the only one that cause the decline of production number; there are other factors.

An approachment is desired to help the government making the right decisions in the development of agroindustry. Decision support system (DSS) is used to decision complex system. DSS provides problem solving and communicate problems with semistructured and unstructured conditions. Suroso and Ramadhan (2011) used the concept of DSS to decide on investments in the agribusiness sector. Yuliana (2013) used a DSS to increase sustainable productivity on fisheries agro supply chain management industries. Hadiguna (2012) also introduced the use of DSS in a sustainable supply chain to determine risk assessment of several risk indicators.

This research is made as a framework for government decisions in the development of patchouli oil industry. System dynamics is a systematic approach that is used in generating predictions of the state in the future, understanding system behavior, and the possibility of users in determining input in the form of simulation scenarios (Lyneis, 2000). The system dynamics approach can accommodate complexity and nonlinearity in both the social network and the physical system (Forrester, 1994). According to Sterman (2000), system dynamics approach requires formal models and simulation to test and improve new policies. According to Suryani (2005), system dynamic simulation is a continuous simulation developed by Jay Forrester (MIT) in the 1960s, focusing on the structure and behavior of the system consisting of variables and feedback loops.

Systems dynamic is used widely in various fields of research such as supply chain modeling, system behavior patterns, policy optimization, decision making, and strategy development. Li, Ren, and Wang (2016); Azadeh and Arani (2016); Teimoury, Nedaei, Ansari, and Sabbaghi (2013); Golroudbary and Zahraee (2015); and Demczuk and Padula (2017) used system dynamic approach in modeling supply chains. Sundarakani, Sikdar, and Balasubramanian (2014) and Tian, Govindan, and Zhu (2014) make policy models to expand the application of green supply chain management. System dynamic can determine the estimated amount of production in uncertain demand conditions at manufacturing system (Poor & Amiri, 2016). Jeong and Adamowski (2016) modeled the use of clean water in a socio-hydrological model; the aim was to see patterns of water use. The same thing was done by Feng et al. (2016) in Hehuang Region of China, but the object of this research was not only water but also involving electricity. Shin, Kwag, Park, and Kim (2017) used the dynamic system to see the effect of the spread of the MERS-CoV outbreak in South Korea.

Ha Tuan, Bosch, Nguyen, and Trinh (2017) compared the income strategies of lowland and highland Vietnamese women farmers using system dynamically. The system dynamics approach can also be used to look at changes in land use and soil testing (Rasmussen, Rasmussen, Reenberg, & Proud, 2012); (Matinzadeh, Koupai, Sadeghi-Lari, Nozari, & Shayannejad, 2017; Inam et al., 2017). The purpose of system dynamics in determining agroindustry development strategies can be seen in the research conducted by Ferreira, Batalha, and Domingos (2016) making an integrated planning model for the citrus business, Walters et al. (2016) developing an agricultural production system in the United States. Ozcan-Deniz and Zhu (2016) use system dynamic in determining policies in construction manipulators with sustainability considerations and also with Barisa, Romagnoli, Blumberga, and Blumberga (2015) using system dynamic in determining consumption patterns and biodiesel policy design in Latvia; Kulakowski et al. (2017) determine conservation and management European mountain forest ecosystem. In the electron field, dynamic systems are also used, namely, to see the effect of the application of radio frequency identification application technology on retail (De Marco, Cagliano, Nervo, & Rafele, 2012).

This study aims to identify data required as input in making agroindustry development decisions using system dynamics. The tools used are dynamic system models to evaluate current policies and simulate future conditions so that the government can learn the most effective and efficient strategies. This research was done by designing stock flow diagrams (SFD) of patchouli oil from the plantation to the exporter. It can show changes in patchouli oil inventory in every agroindustry actor. Changing in stock flow is determined by existing inputs and outputs, where several factors that cause causation effects influence it.

2 | LITERATURE REVIEW

Various previous studies carried out using systems dynamic approach in agriculture can be seen in Table 1. Previous research that has done is categorized based on the results of dynamic system simulation after the run. There are seven categories based on the output aspects, namely, the number of production, demand, social, environmental, technological, and others.

3 | METHODOLOGY

The stages carried out in this research are:

1. Survey and interview to patchouli oil agroindustry actors in West Pasaman regarding problems faced, production processes, and business processes;
2. Literature studies conducted include development of patchouli oil agroindustry and system dynamic;
3. Determine the factors that influence the production process and the patchouli oil business chain in from the level of farmers, intermediary traders, collectors, and exporters;
4. Determine the mathematical relationship between related factors;
5. Making SFD;
6. Determine input and output of system dynamic. Output will help the government in evaluating and setting policies in the future.

SFD was presented in more detail than the causal loop diagram because it contained programming equations and logic that accumulated changes in variable values dynamically over time. SFD in this study divided into four subsystems, namely, patchouli oil agroindustry plantation section, patchouli oil agroindustry farmer section, patchouli oil agroindustry collector section, and patchouli oil agroindustry exporter section.

Data collected through:

1. Interviewing five farmers, three intermediate traders, two collectors, and one exporter. Farmers are in two villages in West Pasaman Regency; intermediaries and collectors at Simpang Empat, West Pasaman Regency; and exporters in Padang;
2. Identifying at Indonesia National Statistics Centre and Indonesia Directorate General of Plantations.

4 | RESULT

SFD is one way to present the system structure with more detailed information. Stocks (levels) are significant variables to produce behavior in a system. Floes (rates) reflects the rate of change that causes changes in the value of stocks. SFD function connect conceptual models with mathematical equation models in relationships between variables (Marques, 2010).

TABLE 1 Use of systems dynamic in agriculture

Researcher	Topic	Result						
		Profit	Production	Demand	Social	Environment	Technology	Others
Chapman and Darby (2016)	Determine the influence of new strategies applied to profits, yields, social societies, and technology in the rice industry in Vietnam	x	x		x		x	
Pasha (2017)	Development of a palm oil supply chain model to increase productivity using a dynamic system		x					
Teimoury et al. (2013)	Development a multi-objective model to make import policies for decomposing vegetables and fruits		x	x				Price
Ferreira et al. (2016)	Designing a model of system dynamics to assess whether integrated mechanisms of agricultural and industrial production planning can improve the competitive performance of citrus agris systems in Brazil	x	x					Price
Mahbubi (2015)	Analysis of the behavior of dynamic supply industrial chain systems sugar on Madura Island for the next few years based on aspects economic, social, and environmental	x			x	x		
Arimurti and Suryani (2014)	Solving the problem of the availability of rice and sugar and provide scenarios in increasing the fulfillment of the availability of rice and sugar and increasing the effectiveness and efficiency of supply chain management		x					
Hidayat, Suryani, and Hendra (2016)	Improving effectiveness and efficiency logistics in the food supply chain							Logistic cost
Jeong and Adamowski (2016)	Development and verify socio-hydrological models using system dynamics	x			x		x	Policies
Ribeiro et al. (2014)	Determinating the influence of policy changes on agricultural business in southern Portugal							agricultural intensity index
Rahmayanti et al. (2017)	Analyzing the potential of oil patchouli in West Pasaman	x	x					
Herry et al. (2011)	Prediction the value of sustainable indicators of rice teri in the Tuban area		x					
Aminudin, Mahbubi, and Puspita (2014)	Identifying basic supply chain systems and problems in potato agribusiness and knowing the system, formulation of potato supply chain models for achievement in national food security	x			x	x		
Ghiffari, M.A., Purnomo, B.H., Novijanto, N. (2016)	Designing system dynamic models for performance appraisal to get the best policy scenario at PT.GMIT Jembe	x	x					
Wardono and Utomo (2013)	Designing policy model for developing catfish culture to support aquaculture production through a dynamic model approach		x	x				Price

4.1 | Patchouli oil agroindustry plantation section

Patchouli oil comes from the extraction of dried both patchouli leaves and stems. The amount of patchouli production strongly influenced by the available planting area. In the current conditions, there are three possible patchouli plants, which are productive patchouli plants ready to be harvested, productive patchouli plants that are not prepared to collect, and aging nonproductive patchouli plants. Productive patchouli plants that are ready to be harvested are usually 8-month-old patchouli plants. Non-positive plants are plants that cannot be harvested, the length of harvest depends on the age of the plant at this time. Whereas for plants that have not produced, replanting is done. The number of patchouli plants for each condition at any time tends to change—changes that occur in each situation influenced by several factors including the amount of patchouli oil demand, the storage time of patchouli oil, the number of patchouli planting areas, the attack of plant pests, the number of available agricultural regions, and so forth.

Planting new patchouli plants is determined by the amount of patchouli oil demand and the number of planting areas available. The new patchouli plant meant planting patchouli over a new planting area that had never planted with patchouli. The newly planted patchouli plants will not succeed 100%; there is some percent that experience crop failure. Crop failure usually occurs due to pest attacks. Regularly, plants attacked by pests will be maintained; if it is not possible, replanting will be carried out. The same thing happened; the plants that planted again would also not be successful 100%. There is a percentage of failures caused by pest attacks.

The number of productive patchouli plants that have not harvested obtains from the planting of new patchouli plants that have been released from pests and replanting patchouli plants that have been free from pests. Replanting is replanting aging plants or replanting new plants that have been affected by pests. Patchouli plants harvested in the form of wet patchouli takes several days to dry. Figure 1 shows the SFD agroindustry on the plantation. There is a cycle starting from opening new planting areas, planting, then maintaining patchouli plants, waiting for harvest, replanting, and so on.

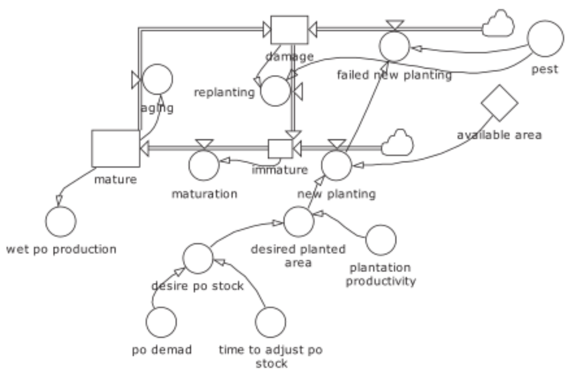

FIGURE 1 Stock flow diagrams plantation section

The mathematical relationship between variables, parameters, and levels can be stated as follows:

$$Immature\,(t) = \int_{to}^{t}[new\ planting(s) + replanting(s) - maturation(s)]ds + immature(t0), \quad (1)$$

$$mature(t) = \int_{t0}^{t}[maturation(s) - aging(s)]ds + mature(t0), \quad (2)$$

$$damage(t) = \int_{t0}^{t}[aging(s) + failed\ new\ planting(s) - replanting(s)]ds + damage(t0), \quad (3)$$

$$\text{desired planted area}_t = \frac{\text{desired po stock}_t}{\text{plantation productivity}_t},$$

$$\text{desired po stock}_t = \frac{\text{po demand}_t}{\text{time to adjust po stock}},$$

$$\text{new planting}_t = \text{if available area}_t > \text{desired planted area}_t,$$

$$\text{desired planted area}_t \text{ else available area}_t,$$

$$\text{failed new planting}_t = \frac{\text{new planting}_t \text{xpest}}{(1 - \text{pest})},$$

$$\text{maturation}_t = \frac{\text{immature}_t}{\text{maturation period}},$$

$$\text{aging}_t = \frac{\text{mature}_t}{\text{aging period}},$$

$$\text{replanting}_t = \frac{\text{damage}_t}{\text{replanting period}},$$

4.2 | Patchouli oil agroindustry farmers section

Wet patchouli leaves and stems are dried with the help of sunlight. Usually, the drying process lasts 2 days if the weather is good or 1 week if not drying it can reach 1 week. Some farmers do drying with the help of simple tools. A simple tool designed in the form of a pallet placed above waiting for distillation so that the heat from the furnace can accelerate the drying process. But unfortunately, this cannot be done for large amounts of drying due to limited space. The remaining dry patchouli weight is usually only 30% of the wet patchouli; then, the distillation process is carried out. Before the patchouli is distilled, the leaves and patchouli stems are cut into smaller parts. The refining process lasts 5–7 hr; this process determines the quality of patchouli oil. The method of distillation in a hurry using high fire will reduce the quality and quantity of patchouli oil produced—patchouli oil only as much as about 2% of the amount of dried patchouli.

The refining rate and the rate of sales influence the amount of patchouli oil stock at the farm level. The sales rate is affected by the amount of patchouli oil supplied by farmers. The difference in the amount of demand for patchouli oil and the amount of patchouli oil stock in the farm that causes the need for patchouli oil is not always full optimally. There is a minimization function to determine the optimal selling rate at the farmer level. There are parameters of patchouli oil storage time that must be considered to determine the sale rate. Selling of patchouli oil is carried out on the collector or intermediary trader; from interviews with farmers in West Pasaman, 70% patchouli oil is sold to collectors, the rest through intermediary traders. Figure 2 is an SFD of the process of processing and sale patchouli oil at the level of farmers.

The mathematical relationship between variables, parameters, and levels for each causal factor can be seen as follows.

$$\text{farmer po inventory}\ (t) = \int_{to}^{t} [\text{rate po yield}(s) - \text{po shipment trader}(s) - \text{po shipment collector}(s)]\, ds + \text{farmer po inventory}(t0), \quad (4)$$

$$\text{dry po production}_t = \text{wet po production}_t\ x\text{reduction},$$
$$\text{rate po yield}_t = \text{dry po production}_t\ x\%\text{rendemen},$$
$$\text{max po supplying}_t = \text{rate po yield}_t + \frac{\text{farmer po inventory}_t}{\text{saving time}},$$
$$\text{po shipment trader}_t = \text{minimum}\left\{\text{po demand trader}_t, \text{max po supplying}_t\ x\frac{\text{po demand trader}_t}{\text{po demand}_t}\right\},$$
$$\text{po shipment collector}_t = \text{minimum}\left\{\text{po demand collector}_t, \text{maxpo supplying}_t\ x\frac{\text{po demand collectors}_t}{\text{po demand}_t}\right\}.$$

4.3 | Patchouli oil agroindustry subsystem collector section

The stock dynamics of patchouli oil at the collecting level influenced by the rate of purchase and the percentage of the sale of patchouli

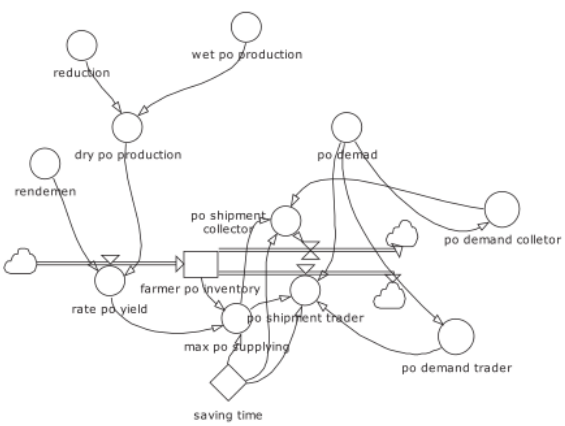

FIGURE 2 Stock flow diagrams farmer section

oil. Collectors buy patchouli oil directly to farmers and through intermediaries—the rate of sales determined by the minimum between demand and the maximum sales that can be done by the collector. The storage time of patchouli oil also affects the maximum sales that can be done by farmers in contrast to the total demand for patchouli oil at the farm level, the level of demand for patchouli oil in traders derived from the total demand of exporters, although the overall market for patchouli oil at the farmer level consists of total overseas and domestic demand. Figure 3 shows the SFD of the purchase and sale of patchouli oil at the collecting level.

The mathematical relationship between variables, parameters, and levels for each causal factor can be seen as follows.

$$\text{collector po inventory}\ (t) = \int_{to}^{t} [\text{po production collector}(s) - \text{po shipment at collector}(s)]\, ds + \text{collector po inventory}(t0), \quad (5)$$

$$\text{po production on collector}_t = \text{po shipment trader}_t + \text{po shipment collector}_t, \text{po shipment at collector}_t = \text{minimum}\{\text{total po demand exp}_t, \text{maxpo collecting supplying}_t\ x1\}.$$

4.4 | Patchouli oil agroindustry subsystem exporter section

The rate of sale of patchouli oil at any time and the amount of patchouli oil at the exporter level determine the amount of patchouli oil demand to the collector. Exporters will only buy patchouli oil from collectors, farmers, or intermediary traders who cannot sell directly to exporters because minimum purchase limit of exporters is 30 kg; at the level of farmers or intermediaries, it is quite challenging to collect patchouli oil up to that amount. Exporters have a maximum inventory amount; orders will be made taking into account the maximum inventory, storage time, and the number of shipments. Figure 4 shows the SFD at the exporter level.

The mathematical relationship between variables, parameters, and levels for each causal factor can be seen as follows:

$$\text{exporter po inventory}\ (t) = \int_{t0}^{t} [\text{total po demand exp}(s) - \text{shipment}(s)]\, ds + \text{exporter po inventory}(t0), \quad (6)$$

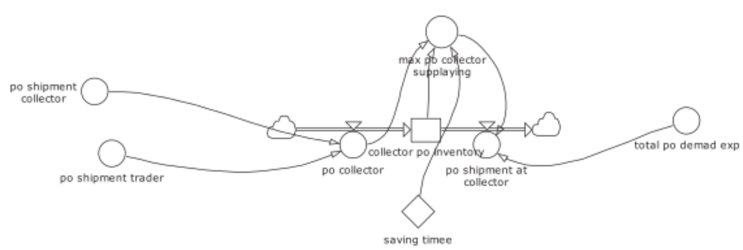

FIGURE 3 Sstock flow diagrams collector section

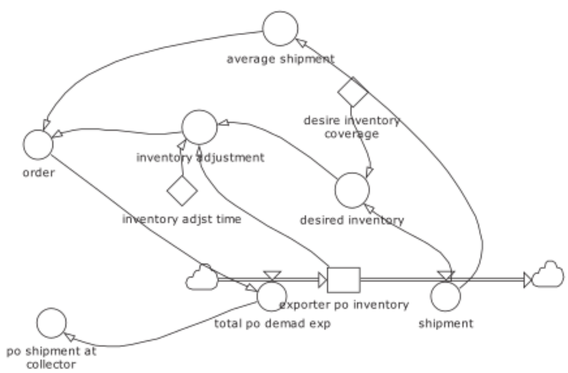

FIGURE 4 Stock flow diagrams exporter section

$$desired\ inventory_t = shipment_t\ x desire\ inventory\ coverage,$$

$$inventory\ adjustment_t = \frac{(exporter\ po\ inventory_t - desired\ inventory_t)}{inventory\ adjst},$$

$$maxpo\ supplaying_t = rate\ po\ yield_t + \frac{farmer\ po\ inventory_t}{saving\ time},$$

$$order_t = inventory\ adjustment_t + average\ shipment_t.$$

5 | DISCUSSION AND CONCLUSION

5.1 | Discussion

Tedeschi (2011) stated that system dynamics (SD) is a computer-aided modeling methodology that can be used to perform policy analysis and DSS applied to dynamic problems arising in complex social, managerial, economic, or ecological dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality. Decision support systems can use the analytic hierarchy approach as done by Ghodsypour and Brien (1998) in choosing the supplier and also Fuzzy (Liang, Wu, & Wu, 2002). The design of SFD as part of a dynamic system simulation gives an overview of inputs and outputs needed to determine the policy of patchouli oil agroindustry development. The systems dynamic model made for patchouli oil agroindustry can show the dynamics of each factor. This model illustrates the current patchouli agroindustry system so that it can be used to test policies to be taken by the government as policy makers.

Systems dynamic characteristics can be seen from the SFD that has made for four patchouli oil agroindustry conditions. According to Sterman (2000), the attributes of a systems dynamic are a complex system, changes in system behavior over time, feedback systems. A complex system in patchouli oil agroindustry subsystem is seen in determining levels for each condition. Patchouli oil stock in each actor influenced by the variable rate of sales and the rate of purchase. While the percentage of buying and selling also affected by several variables, and parameters. Production rate at the farm level influenced by the quality and number of dried patchouli leaves and the technology used.

Changes in system behavior at any time can see from the difference in the amount of patchouli oil stock in each actor. The amount of inventory that is affected by the rate of production and the percentage of sales and purchases tends to change over time due to changes in the variables and parameters that influence them. The feedback mechanism shipping rate that affects the amount of order or demand for patchouli oil, whereas demand affects purchase exporters and purchase collectors. Furthermore, the percentage of the purchase will change the amount of stock in the exporter. The amount of inventory will affect the amount of patchouli oil shipments, and so on.

SFD designed are a significant part of a systems dynamic model. Patchouli oil agroindustry model contributes to presenting the framework for aspects of causality, nonlinearity, dynamics, and endogenous behavior of the system. Furthermore, it can provide experimental experience for policy makers based on the expression of the supporting factors of the system. Moreover, it makes it easy to create simulation scenarios as desired. Furthermore, the SFD patchouli oil industry can be a source of information from written to numerical so that the resulting simulation model more complete and representative. SFD can produce a model structure from managerial inputs and simulate it through quantitative computational procedures in the next stage. Furthermore, the SFD patchouli oil industry can be a source of information from written to numerical so that the resulting simulation model more complete and representative. SFD can produce a model structure from managerial inputs and simulate it through quantitative computational procedures in the next stage.

This study successfully identify the inputs required to develop patchouli oil agroindustry using dynamic systems. The input model of patchouli oil agroindustry development is divided into four groups, namely, plantation section, farmer section, collector section, and exporter section. The data needed for the Plantation Section are as follows:

1. Patchouli demand in West Pasaman;
2. Plantation productivity, the amount of patchouli oil produced in one-hectare area;
3. The number of forest areas available for planting;
4. Nonproductive areas, patchouli planting area has not yet produced;
5. Productive areas, patchouli planting area produces;
6. Patchouli harvest time, the time between patchouli planting to cropping;
7. The productive age of patchouli plants;
8. Percentage of crop failure due to pest attacks.

The input data are processed using the Equations (1) to (3) to produce useful information for the government as policy makers. The input data required for the farmer stage are as follows:

1. Percentage of patchouli depreciation;
2. Percentage yield;
3. Patchouli oil demand by the collector;
4. The maximum length of patchouli oil stock.

The above data processed with Equation (4) become graph or table. The essential data input for the collector section are as follows:

1. Maximum patchouli oil stock;
2. Demand for patchouli oil from exporters.

These data will be processed using Equation (5). Information that will obtain from this subsystem is the amount of patchouli oil shipments from collectors to exporters. The urgency data input for exporters are as follows:

1. Maximum order time, maximum length of time to meet delivery targets;
2. Amount of shipment;
3. Maximum inventory;
4. Maximum patchouli oil stock time.

These data processed with Equation (6) so that it becomes useful information for patchouli oil orders from exporters to collectors. The number of orders from exporters is the primary determinant of the amount of patchouli oil production in West Pasaman because domestic demand is still relatively small when compared with the foreign market.

5.2 | Conclusion

Patchouli oil industry is one industry that is quite potential to be developed in West Pasaman because it has many benefits to the surrounding community. But now, the number of patchouli oil production in West Pasaman is unstable, tends to decrease. The stakeholder government has a significant role in increasing the amount of output and productivity of patchouli oil. In this case, a policy is needed by the government to develop patchouli oil agroindustry. This research builds a framework that helps the government to make decisions on conditions that are considered complex. The approach used is a system dynamic, it is very suitable for complex and high dynamics situation. This study designed the SFD development of patchouli oil agroindustry. From the results of the SFD design, it can conclude that the input needed to obtain the output of the dynamic system. The output generated from the system dynamics will be used as a basis for policy making by the government regarding the development of patchouli oil agroindustry.

This study was a success to identify the inputs required to develop patchouli oil agroindustry using dynamic systems. The input model of patchouli oil agroindustry development divided into four groups, namely, plantation section, farmer section, collector section, and exporter section. The data needed for the plantation section are patchouli demand in West Pasaman, plantation productivity, nonproductive areas, productive areas, patchouli harvest time, the productive age of patchouli plants, and percentage of crop failure due to pest attacks. The input data required for the farmer stage are the percentage of patchouli depreciation, percentage yield, patchouli oil demand by the collector, and the maximum length of patchouli oil stock, whereas the essential data for the collector section are maximum patchouli oil stock and demand for patchouli oil from exporters. The urgency data for exporters are maximum order time, amount of shipment, maximum inventory, and maximum patchouli oil stock time.

SFD patchouli oil agroindustry is a significant part of the systems dynamic of patchouli oil agroindustry. The design of the patchouli oil agroindustry SFD serves as the presentation of the framework from various aspects, providing an innovative experience for policy makers, making it easy to create simulation scenarios as desired. Furthermore, the SFD patchouli oil industry can be a source of information from written to numerical so that the resulting simulation model more complete and representative. SFD can produce a model structure from managerial inputs and simulate it through quantitative computational procedures in the next stage. Although the systems dynamic of patchouli oil agroindustry serves as an evaluation tool for current policies on patchouli oil production, policy evaluation is done by simulation techniques to predict future conditions through scenarios.

ACKNOWLEDGEMENT

The author is grateful to Indonesia Education Fund Management Agency (LPDP) for supporting this research under grant Beasiswa Unggulan Dosen Indonesia 2016.

ORCID

Dina Rahmayanti https://orcid.org/0000-0002-9821-6509

REFERENCES

Aminudin, M., Mahbubi, A., & Puspita, R. A. (2014). Simulation of the potato supply chain dynamic system model in national food security efforts. *Agribusiness Journal*, *8*(1), 1–14.

Arimurti, S. N., & Suryani, E. (2014). Penerapan Sistem Dinamik Untuk Meningkatkan Efektivitas dan Efisiensi Pada Manajemen Rantai Pasok Terhadap Ketersediaan Beras dan Gula di Subdivre 1 Jawa Timur Surabaya,Sidoarjo dan Gresik. *Jurnal Teknik Pomits*, *1*(1).

Azadeh, A., & Arani, H. V. (2016). Biodiesel supply chain optimization via a hybrid system dynamicsmathematical programming approach. *Renewable Energy*, *93*, 383–403. https://doi.org/10.1016/j.renene.2016.02.070

Barisa, A., Romagnoli, F., Blumberga, A., & Blumberga, D. (2015). Future biodiesel policy designs and consumption patterns in Latvia: a system dynamics model. *Journal of Cleaner Production*, *88*, 71–82. https://doi.org/10.1016/j.jclepro.2014.05.067

Central Statistics Agency. (2015). *Statistics Indonesia 2015*. Jakarta: Central Statistics Agency.

Chapman, A., & Darby, S. (2016). Evaluating sustainable adaptation strategies for vulnerable mega-deltas using system dynamics modelling: rice agriculture in the Mekong Delta's An Giang Province, *Vietnam*. *Science* *of the Total Environment*, *559*, 326–338. https://doi.org/10.1016/j.scitotenv.2016.02.162

De Marco, A., Cagliano, A. C., Nervo, M. L., & Rafele, C. (2012). Using system dynamics to assess the impact of RFID technology on retail operations. *International Journal of Production Economics*, *135*, 333–344. https://doi.org/10.1016/j.ijpe.2011.08.009

Demczuk, A., & Padula, A. D. (2017 February). Using system dynamics modeling to evaluate the feasibility of ethanol supply chain in Brazil: the role of sugarcane yield, gasoline prices and sales tax rates. *Biomass and Bioenergy*, *97*, 186–211. https://doi.org/10.1016/j.biombioe.2016.12.021

Directorate General of Plantation (2016). *Indonesian plantation statistics of patchouli commodities 2015–2017*. Ministry of Agriculture: Jakarta.

Feng, M., Liu, P., Li, Z., Zhang, J., Liu, D., & Xiong, L. (2016). Modeling the nexus across water supply, power generation and environment systems using the system dynamics approach: Hehuang Region, *China*. *Journal of Hydrology*, *543*, 344–359. https://doi.org/10.1016/j.jhydrol.2016.10.011

Ferreira, J. O., Batalha, M. O., & Domingos, J. C. (2016). Integrated planning model for citrus agribusiness system using systems. *Computers and Electronics in Agriculture*, *126*, 1–11. https://doi.org/10.1016/j.compag.2016.04.029

Forrester, J. W. (1994). System dynamics, systems thinking, and soft or. *System Dynamics Review*, *10*(2).

Ghodsypour, S. H., & Brien, C. O. (1998). A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. *International Journal of Production Economics*, *56*(56–57), 199–212.

Golroudbary, S. R., & Zahraee, S. M. (2015). System dynamics model for optimizing the recycling and collection of waste material in a closed-loop supply chain. *Simulation Modelling Practice and Theory*, *53*(2015), 88–102.

Ha Tuan, M., Bosch, O. J., Nguyen, N. C., & Trinh, C. T. (2017, January). System dynamics modelling for defining livelihood strategies for women smallholder farmers in lowland and upland regions of northern Vietnam: a comparative analysis. *Agricultural Systems*, *150*, 12–20.

Hadiguna, R. A. (2012). Decision support framework for risk assessment of sustainable supply chain. *Int. J. Logistics Economics and Globalisation*, *4*(1/2), 35. https://doi.org/10.1504/IJLEG.2012.047213

Herry, B., et al. (2011). Model prediksi indikatorkeberlanjutan sumberdaya agroindustri teri nasi kering menggunakan sistemdinamik. *Agrointek*, *5*(2).

Hidayat, S., Suryani, E., & Hendra, R. A. (2016). Spatial system dynamic to increase the effectiveness and efficiency of logistics in the food supply chain. *Integer Journal*, *1*(2), 43–52.

Inam, A., Adamowski, J., Prasher, S., Halbe, J., Malard, J., & Albano, R. (2017). Coupling of a distributed stakeholder-built system dynamics socio-economic model with SAHYSMOD for sustainable soil salinity management. Part 2: model coupling and application. *Journal of Hydrology*, *551*, 278–299. https://doi.org/10.1016/j.jhydrol.2017.03.040

Jeong, H., & Adamowski, J. (2016). A system dynamics based socio-hydrological model for agricultural wastewater reuse at the watershed scale. *Agricultural Water Management*, *171*, 89–107. https://doi.org/10.1016/j.agwat.2016.03.019

Junaedi, A., & Hidayat, A. (2010). Test the origin of patchouli seedlings (Pogostemon cablin Benth.) in West Pasaman, West Sumatra. *Journal of Forest Product Research*, *28*(3), 241–254.

Kulakowski, D., Seidl, R., Holeksa, J., Kuuluvainen, T., Nagel, T. A., Panayotov, M., … Bebi, P. (2017, March 15). A walk on the wild side: disturbance dynamics and the conservation and management of European mountain forest ecosystems. *Forest Ecology and Management*, *388*, 120–131. https://doi.org/10.1016/j.foreco.2016.07.037

Li, C., Ren, J., & Wang, H. (2016). A system dynamics simulation model of chemical supply chain transportation risk management systems. *Computers and Chemical Engineering*, *89*, 71–83. https://doi.org/10.1016/j.compchemeng.2016.02.019

Liang, H., Wu, Z., and Wu, Q. 2002. A decision support system for operations in a container terminal. Proceedings of the 4th World Congress on Intelligent Control and Automation (Cat. No.02EX527), **ISBN:** 0–7803–7268-9, 10–14 June 2002.

Lyneis, J. M. (2000). System dynamics for market forecasting and structural analysis. *System Dynamics Review*, *16*, 3–25. https://doi.org/10.1002/(SICI)1099-1727(200021)16:1<3::AID-SDR183>3.0.CO;2-5

Matinzadeh, M. M., Koupai, J. A., Sadeghi-Lari, A., Nozari, H., & Shayannejad, M. (2017). Development of an innovative integrated model for the simulation of nitrogen dynamics in farmlands with drainage systems using the system dynamics approach. *Ecological Modelling*, *347*, 10 March 2017, 11–28. https://doi.org/10.1016/j.ecolmodel.2016.12.014

Ozcan-Deniz, G., & Zhu, Y. (2016). A system dynamics model for construction method selection with sustainability consideration. *Journal of Cleaner Production*, *121*, 33–44. https://doi.org/10.1016/j.jclepro.2016.01.089

Poor, R., & Amiri, M. (2016). A system dynamics modeling approach for a multi-level, multi-product, multi-region supply chain under demand uncertainty. *Expert Systems with Applications*, *51*, 231–244.

Rahmayanti, D. Hadugna, R. A., Santosa, & Nazir, N. (2017). System Dynamics of Farmer Income and Patchouli Oil Production. National Seminar on Information, Communication and Industry Technology (SNTIKI) 9, Faculty of Science and Technology, UIN Sultan Syarif Kasim Riau, Pekanbaru, 18–19 Mei 2017.

Rasmussen, L. V., Rasmussen, K., Reenberg, A., & Proud, S. (2012, March). A system dynamics approach to land use changes in agro-pastoral systems on the desert margins of Sahel. *Agricultural Systems*, *107*, 56–64. https://doi.org/10.1016/j.agsy.2011.12.002

Ribeiro, P. F., Santos, J. L., Bugalho, M. N., Santana, J., Reino, L., Beja, P., & Moreira, F. (2014). Modelling farming system dynamics in high nature value farmland under policy change. *Agriculture, Ecosystems and Environment*, *183*, 138–144. https://doi.org/10.1016/j.agee.2013.11.002

Shin, N., Kwag, T., Park, S., & Kim, Y. H. (2017, May 21). Effects of operational decisions on the diffusion of epidemic disease: a system dynamics modeling of the MERS-CoV outbreak in South Korea. *Journal of Theoretical Biology*, *421*, 39–50. https://doi.org/10.1016/j.jtbi.2017.03.020

Sterman, J. D. (2000). *Business dynamics systems thinking and modeling for a complex world*. McGraw-Hill.

Sundarakani, B., Sikdar, A., & Balasubramanian, S. (2014). System dynamics-based modelling and analysis of greening the construction industry supply chain. *International Journal of Logistics Systems and Management*, *18*(4), 517–537. https://doi.org/10.1504/IJLSM.2014.063983

Suroso, A.I., Ramadhan, A. (2011). Decision Support System for Agribusiness Investment as e-Government Service Using Computable General Equilibrium Model. Proceedings of the 2011 2nd International Congress on Computer Applications and Computational Science, 157–162.

Suryani, E. (2005). *Pemodelan dan Simulasi*. Yogyakarta: Graha Ilmu.

Teimoury, E., Nedaei, H., Ansari, S., & Sabbaghi, M. (2013). A multi-objective analysis for import quota policy making in a perishable fruit and vegetable supply chain: a system dynamics approach. *Computers and Electronics in Agriculture*, *93*, 37–45. https://doi.org/10.1016/j.compag.2013.01.010

Tian, Y., Govindan, K., & Zhu, Q. (2014). A system dynamics model based on evolutionary game theory for green supply chain management diffusion among Chinese manufacturers. *Journal of Cleaner Production*, *80*, 96–105. https://doi.org/10.1016/j.jclepro.2014.05.076

Walters, J. P., Archer, D. W., Sassenrath, G. F., Hendrickson, J. R., Hanson, J. D., Halloran, J. M., … Alarcon, V. J. (2016, August 10). Exploring agricultural production systems and their fundamental components with system dynamics modelling. *Ecological Modelling*, *333*(2016), 51–65. https://doi.org/10.1016/j.ecolmodel.2016.04.015

Wardono, B., & Utomo, B. P. (2013). Rancang Bangun Kebijakan Pengembangn Budidaya Lele melalui Pendekatan Model Dinamik. *Jurnal Kebijakan Sosial Ekonomi Kelautan dan Perikanan*, *3*(2).

Yuliana, K., Teniwut, and Marimin, (2013). Decision support system for increasing sustainable productivity on fishery agroindustry supply chain. 2013 International Conference on Advanced Computer Science and Information Systems (ICACSIS), **ISBN:** 978–1–4799-4692-1, 13 March 2014.

How to cite this article: Rahmayanti D, Hadiguna RA, Santosa S, Nazir N. Conceptualization of system dynamic for patchouli oil agroindustry development. *Bus Strat Dev*. 2019;XX–XX. https://doi.org/10.1002/bsd2.85

Conceptualization of system dynamic for patchouli oil agroindustry development

ORIGINALITY REPORT

12%	5%	10%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	D Rahmayanti, R A Hadiguna, Santosa, N Nazir. "Applying system dynamic for predicting the strengths, weaknesses, opportunities, and treats of Patchouli Oil Agroindustry in West Sumatra", IOP Conference Series: Materials Science and Engineering, 2021 Publication	3%
2	Dina Rahmayanti, Rika Ampuh Hadiguna, N.A. Santosa, Novizar Nazir. "Applying system dynamic to predict production and market demand of patchouli oil", International Journal of Agriculture Innovation, Technology and Globalisation, 2021 Publication	2%
3	Tedeschi, L.O.. "Using System Dynamics modelling approach to develop management tools for animal production with emphasis on small ruminants", Small Ruminant Research, 201106 Publication	1%

4	industria.ub.ac.id Internet Source	1 %
5	Andriyan Rizki Jatmiko, Erma Suryani, Dhyna Octabriyantiningtyas. "The Analysis of Greenhouse Gas Emissions Mitigation: A System Thinking Approach (Case Study: East Java)", Procedia Computer Science, 2019 Publication	1 %
6	www.dbis.ethz.ch Internet Source	1 %
7	Ferreira, José Orlando, Mário Otávio Batalha, and Jean Carlos Domingos. "Integrated planning model for citrus agribusiness system using systems dynamics", Computers and Electronics in Agriculture, 2016. Publication	<1 %
8	insightsociety.org Internet Source	<1 %
9	I Santoso, YN Afifa, R Astuti, P Deoranto. "Development model on upstream-downstream integration of coffee agroindustry using dynamics modelling approach", IOP Conference Series: Earth and Environmental Science, 2021 Publication	<1 %
10	Pradeep Kautish, Rajesh Sharma. "Determinants of pro‐environmental	<1 %

behavior and environmentally conscious consumer behavior: An empirical investigation from emerging market", BUSINESS STRATEGY & DEVELOPMENT, 2019
Publication

11	Nancy Oktyajati, Muh. Hisjam, Wahyudi Sutopo. "The dynamic simulation model of soybean in Central Java to support food self sufficiency: A supply chain perspective", AIP Publishing, 2018 Publication	<1%
12	"New Perspectives on Enterprise Decision-Making Applying Artificial Intelligence Techniques", Springer Science and Business Media LLC, 2021 Publication	<1%
13	aip.scitation.org Internet Source	<1%
14	Igor Krejčí, Pavel Moulis, Jana Pitrová, Ivana Tichá, Ladislav Pilař, Jan Rydval. "Traps and Opportunities of Czech Small-Scale Beef Cattle Farming", Sustainability, 2019 Publication	<1%
15	ebin.pub Internet Source	<1%
16	etheses.whiterose.ac.uk Internet Source	<1%

17	patpiconference.ftip.unpad.ac.id Internet Source	<1 %
18	rgu-repository.worktribe.com Internet Source	<1 %
19	www.emerald.com Internet Source	<1 %
20	www.testmagzine.biz Internet Source	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		