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System dynamic model of green supply chain management robusta coffee Argopuro in Indonesia: A case study

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ABSTRACT

Small-scale Argopuro Robusta coffee agroindustry has the potential to harm the environment in every supply chain activity. Even though the waste processing process has been carried out, this is still not enough to reduce the environmental impact. Performance measurement of Green Supply Chain Management (GSCM) in the business is complex because it considers environmental indicators and operational business as a whole. GSCM performance is also dynamic because the behavior of the supply chain system often changes over time. Therefore, it is necessary to develop a performance diagnosis model that has complex and dynamic characteristics through a system dynamic model. This research aims to diagnose and improve the GSCM performance index for currently and future using a system dynamic model. The scope of the model starts from harvesting coffee cherries to selling processed products. Research result shows that there are 13 performance indicators. The indicator values are then determined using the system dynamic model to obtain an index value of GSCM. The simulation results show that in 2023, the GSCM performance value will be 35.40, which is included in the good enough status, and 2035 the performance value increase by 54.8. To improve its performance, an optimistic scenario is used. This scenario is built by providing intervention to increase the percentage of waste processing by 90% for solid waste and 70% for liquid waste. Increase the number of pickup trucks by 4 units and reduce the motorcycle by 45 units to be more optimal and reduce the amount of emissions produced. The simulation results show that with that scenario the GSCM performance index was successfully increased to 68.2 (good status) in 2035.

Key words: Green supply chain management; system dynamic model; coffee; policy scenario.

1 INTRODUCTION

Coffee is included in the 10 main export commodities and five leading plantation commodities in Indonesia which have an important role in the national economy. Indonesia was the fourth coffee-producing country in the world after Brazil, Vietnam, and Colombia with an average production of around 760,200 metric tons (Tampubolon et al., 2023). There are two types of coffee cultivated in Indonesia, namely robusta and arabica. Jember Regency, East Java has the potential for coffee development, precisely on the Argopuro mountain slopes. Robusta coffee production from smallholder plantations in Jember Regency reached 3,268 tons or 9.9% of the total production in East Java province, with a plantation area of around 4,942 ha (Director General of Plantations Republic of Indonesia, 2022).

Argopuro smallholder robusta coffee plantation is sent to the coffee processing unit called UPH which improves the quality of the coffee and produces green bean and ground coffee products. One of the farmer groups managing UPH is the Sumber Kembang farmers group located on the slopes of the Argopuro mountains, Jember Regency. Based on the interview results, the coffee plantation area managed by the Sumber Kembang farmers group is around 150 ha with the harvest of coffee berries reaching 6 tons/ha under normal conditions. This large coffee production requires the Sumber Kembang farmer group to manage the supply chain considering that coffee has a perishable nature, inconsistent quality, and the role of each supply chain actor.

Supply chains are activities in changing natural resources, raw materials, and basic components into finished products that will be distributed to final consumers (Chang et al., 2012). The most important roles of stakeholders in the supply chain are farmers, collectors, industry, and consumers (Winarno; Harijani, 2022; Suryaningrat; Novita, 2023). The supply chain network starts from the source that provides the first material so that the subsequent distribution chain will run (Felea; Albăstroiu, 2013).

In every supply chain activity, both food and non-food industries have the opportunity to create pollution, waste, and materials that are dangerous to the environment (Ninlawan et al., 2010; Sabat; Krishnamoorthy, 2018). Coffee processing at the Sumber Kembang farmer group produces solid and liquid waste. Apart from that, activities on coffee plantations and distribution also have the potential to contribute to negative impacts on the environment originating from emissions. According to Giandadewi et al. (2017) emissions (N_2O, CH_4, and CO_2) come from the use of chemical fertilizers, production processes, and transportation processes.

Green Supply Chain Management (GSCM) is a conventional supply chain management concept combined with environmental aspects that aims to eliminate or reduce waste (energy, gas emissions, hazardous chemicals, and waste) in each supply chain network (Sundarakani; Souza; Goh, 2010; Ghobakhloo et al., 2013). Developing and measuring GSCM metrics for the UPH Sumber Kembang farmer group is an important need to understand operational, business, and ecological performance. The resulting performance index is a description of the agro-industry's ability to manage supply chains. To measure the GSCM performance index at UPH Sumber Kembang, a conceptual model needs to be created first in the form of a causal loop diagram. This diagram shows the relationship between variables that influence each other (cause and effect relationship). These variables are complex, dynamic, and probabilistic. System dynamics is a modeling technique used to describe and understand complex problems. System dynamics methodology uses causal relationships in constructing a model of a complex system, as a basis for recognizing and understanding the dynamic behavior of the system (Muhammadi; Soesilo, 2001; Johnson; Penn, 2022). The application of green supply chain management with a system dynamics approach can produce a quantitative model that can predictions for several future periods. In addition, it allows determining reasonable policy scenarios to serve as input for decision-making in reducing waste resulting from supply chain activities.

SCM measurements have only been carried out statically using the SCOR approach. The SCOR model is a complete static platform for measuring business performance and system operations based on the processes that occur (Teixeira; Borsato, 2019). The Green SCOR model began to emerge because of the need to measure the environmental performance of supply chain systems. The indicators used place more emphasis on environmental aspects than business and operational indicators. This will create inequality in assessing the performance of the system being studied. Research related to this was carried out by Rosyidah et al. (2022). In this research, the GSCOR performance matrix was designed which not only emphasizes environmental indicators alone but has integrated indicators in business and operational aspects.

If we look closely, the results of previous research have not been able to accommodate the dynamics and performance behavior of GSCM, even though this system will always develop and change from time to time. The need to build a dynamic and comprehensive quantitative model for measuring GSCM performance is very urgent for policy analysis in system development. Models with characteristics like these can provide accurate information about how the system will behave and its performance status in the future, as well as determine key variables that need to be changed for better system improvements.

2 MATERIAL AND METHODS

This research uses primary and secondary data. Primary data was obtained through field data sampling, interviews, and Focus Group Discussions with research respondents. Meanwhile, secondary data was obtained through data collection from various sources, such as the Jember Regency statistical bureau, documents from coffee processing units, documents from supply chain actors, and published journals.

This research consists of three stages. The first is identifying the supply chain system as well as determining key GSCM performance indicators and their weights. The second is to build a system dynamic model for measuring GSCM performance. System dynamic simulation analysis is processed using Powersim® software. The last one is to develop a policy scenario for increasing the GSCM performance index.

2.1 Identify Key Indicators

Indicators are used to measure the level of GSCM performance achievement at UPH Sumber Kembang. Performance measurement uses the SCOR metric which consists of 5 main attributes, namely reliability, agility, responsiveness, cost and asset management (Paul, 2014). Each attribute consists of one or more Key Performance Indicators (KPI). The Key Performance Indicator is the result of a selection of various indicators obtained by researchers from the synthesis of SCOR metrics in previous studies, then re-selected by experts through the Focus Group Discussion Forum. The selected indicators represent UPH's operational environmental and business performance indicators. The selected key indicators are then weighted by experts using the paired comparison method (Strada; Kułakowski, 2022; Cavallo; Ishizaka, 2023). In this research, 13 performance indicators were obtained as can be seen in Table 3.

2.2 Building System Dynamic Model

2.2.1 Conceptualization Model

The conceptualization model is a concept model in the form of a causal loop diagram that explains the system elements and the relationships between these elements so as to form the structure of the system being studied. Causal loop diagram can explain the mechanisms and dynamic behavior of a system and are useful as a diagnostic tool if the system fails to achieve its goals or performance, as well as exploring why problems arise in achieving system goals (Yan et al., 2023; Yang et al., 2019). The causal loop diagram for the UPH Sumber Kembang GSCM performance assessment system is shown in Figure 1.

The diagram describes that the productivity of the coffee fruit harvest depends on the quantity rainfall. Increasing the productivity of the coffee fruit harvest will increase the number of coffee fruit harvests. Apart from harvest productivity, the number of fruit harvests has increased Coffee is also influenced by the number of plants it produces. Farmers will send the harvested coffee cherries to be used by the produce processing unit (UPH) to produce green beans and ground coffee. This product causes UPH to gain a profit or loss. The profits obtained will influence work motivation of the workforce at UPH, where increasing profits increases the number incentives to be provided. Motivation has a direct effect on increasing workforce skills. Skills will improve increasing the yield of processed products which will ultimately increase business profits. In On the other hand, agro-industrial activities have a negative impact, namely the emergence of emissions resulting from the use of fuel for engines and transportation. The greater the emission value, the better the performance in the environmental dimension decrease.

The relationships that occur between system variables can be in the form of positive or negative relationship patterns. A positive relationship pattern means that an increase in the value of a variable or indicator will influence an increase in other variables or indicators. On the other hand, if an increase in the value of a variable or indicator causes a decrease in the value of another variable or indicator, it is called a negative relationship pattern.

2.2.2 Required Data and analysis method

This research requires important data to determine the values of the model variables as listed in the Causal Loop diagram. These data are processed using relevant analysis methods and the results are used for model variables. Model variables can contain constants, equations, or logic functions (Table 1).

2.2.3 Model Formulation

The simulation model formulation stage uses a computer program, Powersim. The structure is created by building a flow diagram or SFD (Stock Flow Diagram) to be connected at the simulation stage. In making a simulation model, correct mathematical equations, parameters, and determination of initial value conditions are required. By using the Powersim the first thing to do is calculate the initial values used to measure the stock and flow of a flow. Flow is used to update existing stock values. The stock value is used to recalculate as time changes repeatedly.

The number of coffee harvests is an important indicator in this sub-model because it will influence the performance of other system components. The increase in the number of coffee harvests is influenced by two main variables, namely the number of producing plants and harvest productivity. Apart from the frequency of fertilization, rainfall is a variable that greatly influences the growth of coffee plants, thereby affecting the value of harvest productivity.

The variable mature plants are an integral function of the inflow of immature plants reduced by damaged plants. Some equation of the variables in system dynamic model are described as follows.

1. Mature plant$_{(t)}$=Mature plant$_{(t-1)}$+(Immature plant$_{(t)}$-Demaged plant$_{(t)}$)
2. Number of coffee harvest$_{(t)}$=(mature plant$_{(t)}$ *productivity$_{(t)}$) - (mature plant$_{(t)}$ *productivity$_{(t)}$ *transportation loss$_{(t)}$).

The production model is influenced by the yield variable. Yield is the percentage of green beans produced from harvested coffee cherries. According to Jaljala et al. (2022) from 1000 kg of coffee fruit, 200 kg of coffee is produced.

3. Green bean production$_{(t)}$=coffee fruit$_{(t)}$+yield$_{(t)}$

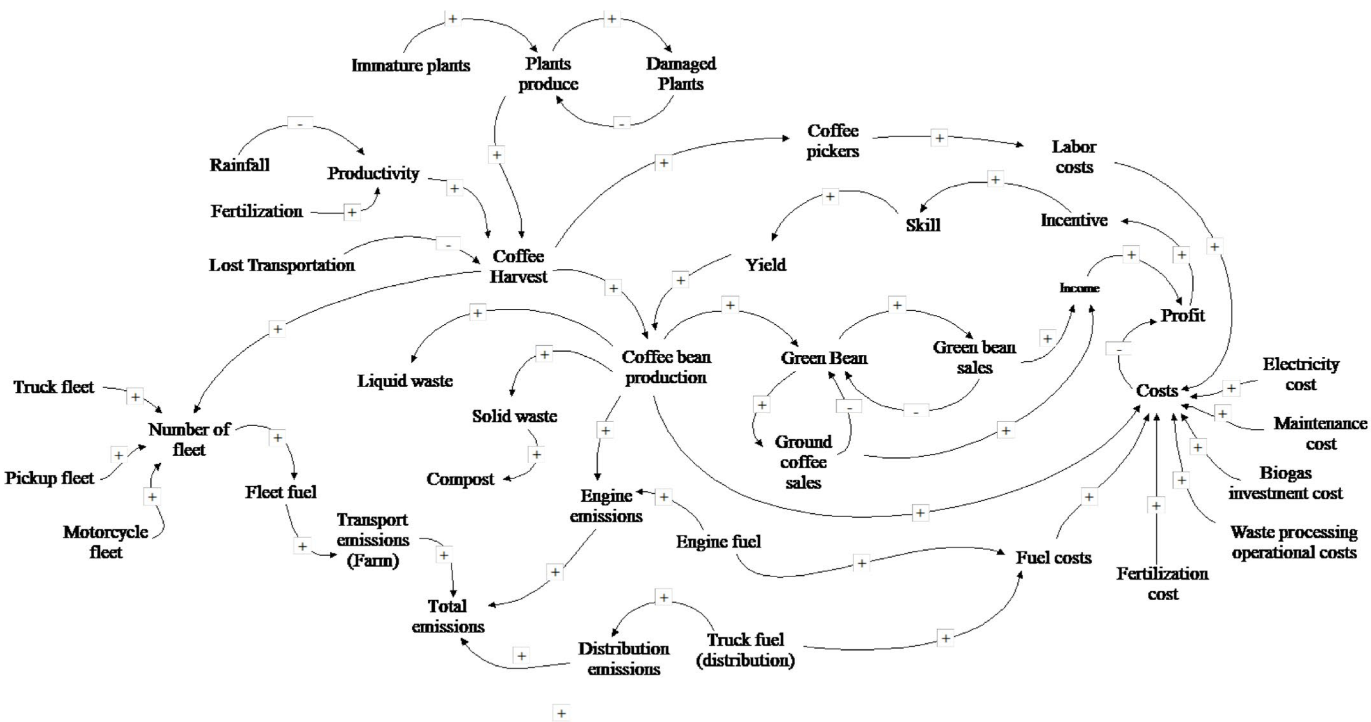

Figure 1: Causal loop diagram.

Table 1: Data research required.

Data	Tipe	Variable	Data analysis
Rainfall in researh location	Time series for 2016-2022	Prediction rainfall	Random
Large of coffee plantations area	Time series for 2016-2022	Determine coffee plantations area	Descriptive statistic (average)
Coffee plants (has produced; not yet produced)	Time series for 2016-2022	Determine the number of coffee plants	Descriptive statistic (average)
The proportion of coffee processed into various product	Time series for 2016-2022	Determine the constant of coffee processed	Descriptive statistic (average)
Production yield	Time series for 2020 - 2022	Determine production yield	Logic function (IF ... Then)
Workforce skill	Observation & interview with several expert	Determine workforce skill	Logic function (IF ... Then)
Conversion into processed product	Observation & interview with several expert	Determine conversion value	Descriptive statistic (proportion)
Sales of coffee product	Time series for 2016-2022	Determine product sale	Descriptive statistic (average)
Selling price	Time series for 2020-2022	Determine product sale	Descriptive statistic (average)
Production cost	Time series for 2020 - 2022	Determine the constant of production cost elements	Descriptive statistic (average)
Amount of fuel used	Observation & interview with several expert	Determine the constant of fuel used per fleet	Descriptive statistic (average)
Emission of fuel used	Desk research	Determine the constant of emission produced	Descriptive statistic (average)
Liquid and solid waste	Observation & interview with several expert	Determine the constant of liquid and solid waste	Descriptive statistic (average and proportion)

The emission sub-model is a description of the emission system resulting from the distribution, processing, and liquid waste activities produced. Total emissions are an important indicator in that it is a variable whose value is used as a reference in determining policy scenarios for decision-making. The total emissions equation is described as follows:

4. Total emissions$_{(t)}$=Farm transportation emissions$_{(t)}$+ Product transportation emissions$_{(t)}$+engine emissions$_{(t)}$

Meanwhile, the quantitative equation in system dynamic model for determining the GSCM indicators value are as follows:

1. The amount of solid waste produced$_{(t)}$=(percentage of solid waste$_{(t)}$*coffee cherry$_{(t)}$)
2. % of solid waste recycled$_{(t)}$=percentage of solid waste recycled$_{(t)}$*solid waste$_{(t)}$
3. The amount of liquid waste produced$_{(t)}$=(percentage of liquid waste$_{(t)}$*coffee cherry$_{(t)}$)”
4. % of liquid waste recycled$_{(t)}$=percentage of liquid waste recycled$_{(t)}$*liquid waste$_{(t)}$
5. Potential CO_2Eq$_{(t)}$=Farm transportation emissions$_{(t)}$+Product transportation emissions$_{(t)}$+Engine emissions$_{(t)}$
6. Make cycle time$_{(t)}$=net production time$_{(t)}$/number of unit produced$_{(t)}$
7. %Stockout$_{(t)}$=(product stock$_{(t)}$-sales amount$_{(t)}$/sales amount$_{(t)}$)*100%
8. %Overstock$_{(t)}$=“(product stock$_{(t)}$-sales amount$_{(t)}$/sales amount$_{(t)}$)*100
9. %Fullfillment of fertilizer needs with alternative fertilizers$_{(t)}$=(amount of compost$_{(t)}$-fertilizer needs$_{(t)}$/fertilizer needs$_{(t)}$)*100%
10. Production costs$_{(t)}$=(fixed costs$_{(t)}$+*variable cost*$_{(t)}$)/total green bean production$_{(t)}$
11. Net profit margin$_{(t)}$=(net income$_{(t)}$/revenue$_{(t)}$)*100%
12. Average inventory$_{(t)}$=(Current inventory$_{(t)}$+Previous inventory$_{(t-1)}$)/Number of periods$_{(t)}$
13. Number of alternative fertilizer and solid waste sold$_{(t)}$=(amount of compost$_{(t)}$+solid waste$_{(t)}$)

Each performance metric has different value units (parameters), so normalization needs to be carried out to equalize the value units (parameters) of each performance metric used to calculate the final GSCM performance value. Calculation of normalization values was obtained using the Snorm De Boer equation (Prasetyo; Emaputra; Parwati, 2021). With this normalization, the performance value will range from 0 to 100. The higher the value, the better the performance, where the value 0 is interpreted as the worst and the value 100 is interpreted as the best. The Snorm De Boer equation 1 is as follows.

1. If the measurement is larger is better:

$$Snorm = \frac{(SI\text{-}Smin)}{Smax\text{-}Smin} x100\% (1)$$

The lower the value, the better the performance, where the value 0 is interpreted as the best and the value 100 is interpreted as the worst. The Snorm De Boer equation 2 is as follows.

2. If the measurement is lower is better:

$$Snorm = \frac{(Smax\text{-}SI)}{Smax\text{-}Smin} x100\%$$

SI = Actual achievement of performance metrics.

S_{max} = Maximum attainment value of the performance metric.

S_{min} = The minimum attainment value of the performance metric.

Next, an analysis of the performance results is carried out referring to the standards which can be seen in Table 2.

Table 2: Performance index category.

Average Score Interval	Information
$0 < X \leq 25$	Not good
$25 < X \leq 50$	Good enough
$50 < X \leq 75$	Good
$75 < X \leq 100$	Very good

2.3 Model Validation

To find out and determine whether the simulation model is running according to the model creator's wishes, a verification process needs to be carried out. Meanwhile, to find out whether the simulation model can represent the real system or conditions accurately, a validation process needs to be carried out. The method used is to test the extent to which the simulation created has shown behavior and responses that are following the objectives of the model (Wynne; Beanland; Salmon, 2019).

Powersim simulation output data results and actual data are compared based on error values with a permissible deviation limit of between 5-10%. MAPE (Mean absolute percentage error) is used to determine the accuracy of the model that has been created or to find out how big the error is (Soedjianto; Oktavia; Anggawinata, 2006). Criteria for model accuracy with the MAPE test 5%<MAPE<10%.

In this research, face validity was also carried out, namely asking for expert assistance to assess whether the logic of the model and the results achieved were considered to represent the real system. According to Sargent (2020), Face validity can be used in validation where experts are asked to make a subjective assessment regarding whether a simulation model has sufficient accuracy capabilities for its intended purpose. Experts must know the system so they can know whether the model logic is correct and has reasonable behavior.

2.4 Policy Analysis

Policies are general rules for how status decisions are made based on available information. It is a composition of several scenarios that have considered several aspects, of which one will be selected as the best policy. This possibility is based on how good the modeler was when creating the model.

3 RESULT

3.1 Identify Supply Chain Systems

Coffee processing by the Sumber Kembang farmer group is carried out using two types of processes, namely natural and fullwash. The coffee processing process produces 50-60 percent solid waste (Khotijah; Novita; Purbasari, 2019; Ningrum; Pramitasari; Kartini, 2023). Meanwhile, in the full wash process, water consumption can reach 7-9 m^3 per ton of coffee fruit (Genanaw et al., 2021).

The flow in this supply chain is in the form of robusta coffee commodities and processed coffee products. Coffee fruit commodities flow from farmers to UPH and factories, while processed coffee products from UPH and factories are in the form of green beans, roasted, and ground coffee products. Coffee fruit from farmers is not only channeled to UPH but is also distributed to small collectors and large collectors. There is no binding contract between farmers and UPH, so farmers have the freedom to sell coffee commodities. Supply chain structure at UPH Sumber Kembang is shown in Figure 2.

3.2 GSCM Key Performance Indicator

The results of the analysis obtained 13 KPIs which represent environmental performance indicators (En) and business operational indicators (OBs) catagories. Determining the weight of each performance indicator is obtained from an expert assessment using the pairwise comparison method. Creating pairwise comparison metrics requires quantities that can describe the differences between one factor and another. The weighting uses the Saaty scale starting from 1 to 9. From this process, 13 indicators and weights were produced which were used to assess the GSCM performance of Argopuro smallholder robusta coffee plantation which is presented in Table 3.

3.3 Model Validation

Model validation is the process of comparing whether the resulting model can represent the real system validly and convincingly. In this research, model validation was carried out using consistent testing of output results by comparing actual results with simulated data based on the calculation of the MAPE statistical test. The data that will be carried out by the MAPE test is the number of coffee harvests.

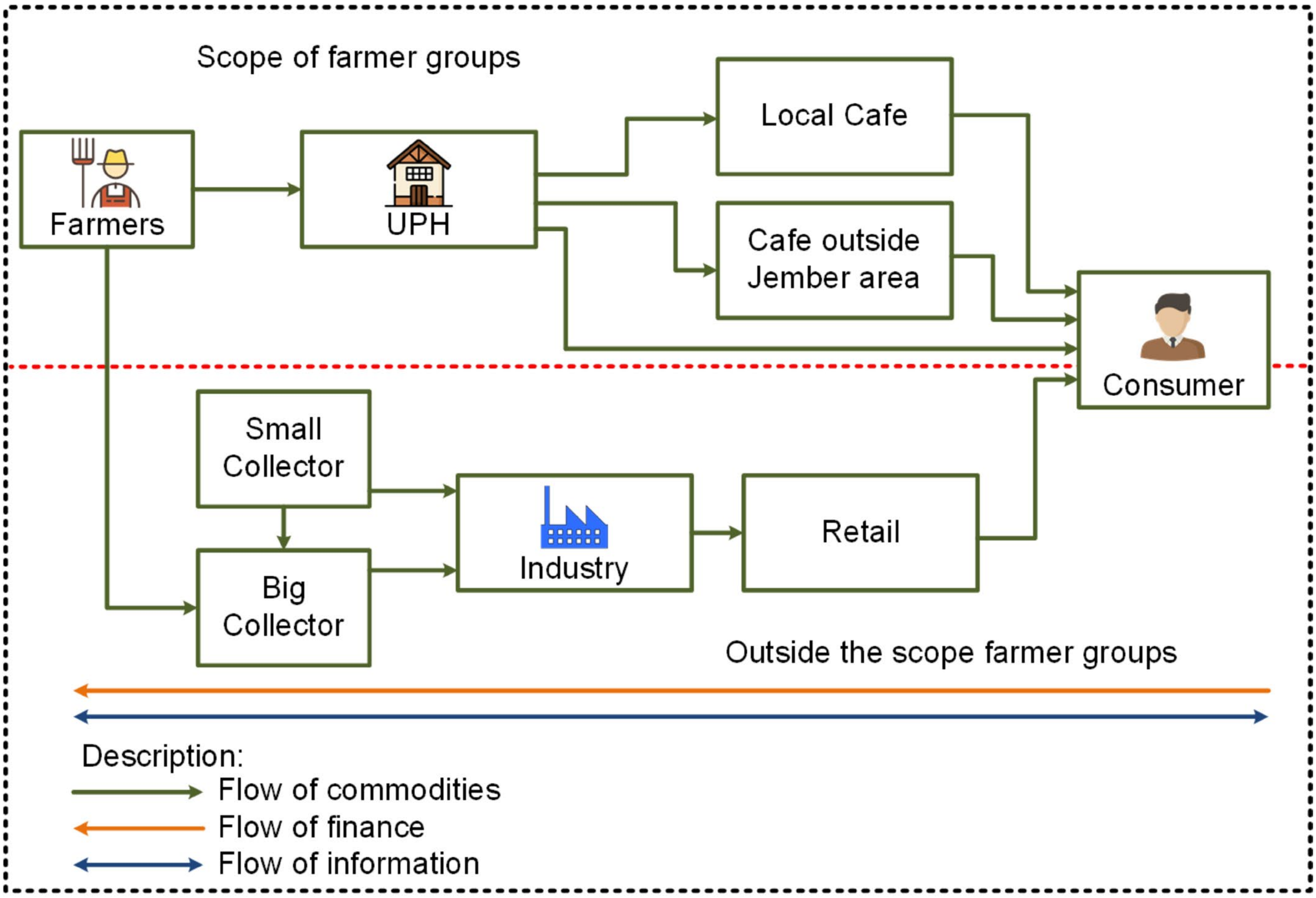

Figure 2: Supply Chain Structure.

Table 3: Performance indicator weights.

Attribute	Performance Indicators	Catagory	Weight
Reliability	The amount of solid waste produced	En	0.080
	% of solid waste recycled	En	0.026
	The amount of liquid waste produced	En	0.065
	% of liquid waste recycled	En	0.022
	Potential CO_2 emissions Eq	En	0.168
Responsiveness	Make Cycle time	OBs	0.154
Agility	% stockout	OBs	0.038
	% overstock	OBs	0.057
	% Fulfillment of fertilizer needs with alternative fertilizers	En	0.037
Cost	Production costs (Rp/kg green beans)	OBs	0.140
Asset Management	Profit margins	OBs	0.137
	Average inventory amount	OBs	0.053
	Number of alternative fertilizers and solid waste sold	En	0.024
Weight total			**1.00**

The MAPE calculation result is 12%, which shows the percentage difference between actual data and simulated data. These results are in the MAPE range of 10-20%, so it can be said that the model has good capabilities so that the method used can be a reference for abilities predictions for several future periods (Moreno et al., 2013; Nabillah; Ranggadara, 2020). The simulation model was built with a random number generator every time the simulation was run to obtain a value for the number of coffee harvests.

To increase the validity of the model, face validity is carried out by analyzing the model's behavior. The system elements whose behavior is analyzed are the number of coffee harvests and the total emissions produced. To see its behavior, the model is simulated for the next 12 years (2035). The behavior of the number of coffee harvests and total emissions is shown in Figure 3. The amount of coffee harvest fluctuates yearly due to the dynamics of harvest productivity due to rainfall. From 2020 to 2023, the number of coffee harvests continues to decline to around 100 tons. The amount of emissions has a behavior that is directly proportional to the amount of coffee harvested, this condition is caused by an increase in fuel use and waste produced. It can be concluded that the behavior of the model variables is quite valid.

3.4 Scenario and GSCM Performance Index

Policy scenarios are developed to improve GSCM performance index value. The scenario is built by establishing several key parameters which, if applied to the model, can increase the value of the GSCM performance index. Determining the policy parameter values is carried out after knowing the results of the model simulation in actual conditions or what is called the basic scenario. The value of this basic scenario is very important as a description of the actual conditions on the robusta coffee plantations of Argopuro, Jember Regency. Changes in these parameters can be the basis for decision making and can be a picture of environmentally friendly supply chain management in the robusta coffee plantations in Argopuro, Jember Regency in the future.

Changes in parameter values are divided into three scenarios, namely the pessimistic scenario, the moderate scenario, and the optimistic scenario. These three scenarios are respectively called the run scenario run scenario 1 (SR1), run scenario 2 (SR2), and run scenario 3 (SR3), while the initial conditions use scenario run 0 (SR0). Changes in the green supply chain scenario in the Argopuro smallholder robusta coffee plantation, Jember Regency based on changes in parameter values are described in Table 4 for the next twelve years.

The ability to manage the agro-industrial supply chain is reflected in the performance of the supply chain. Superior supply chain performance can be assessed from several achievement indicators that can measure the efficiency of a company's business performance (Rahmah; Pulansari, 2022). The GSCM performance index in the basic scenario is presented in Table 5.

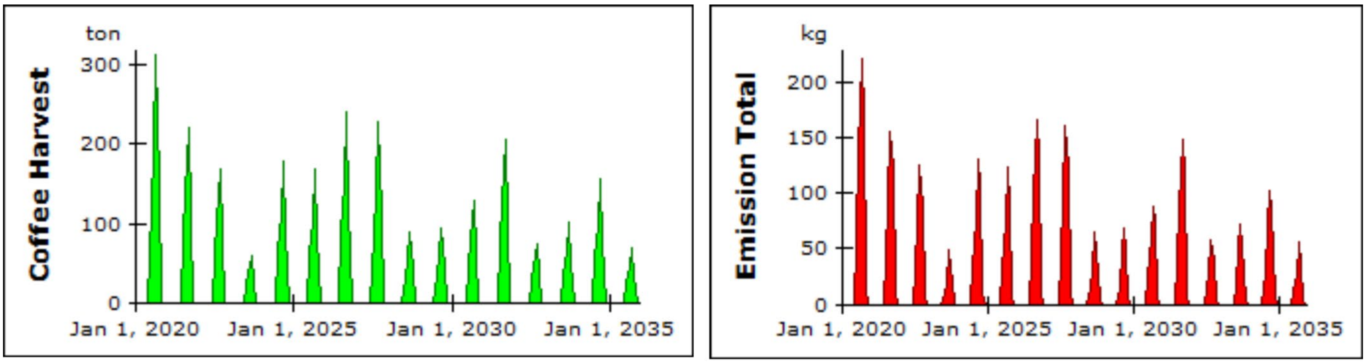

Figure 3: Behavior of the number of coffee harvests and total emissions total.

Table 4: GSCM policy scenarios.

Scenario		Basic (SR0)	Pessimistic (SR1)	Moderate (SR2)	Optimistic (SR3)
Solid waste processing (%)		70	-20	+10	+20
Liquid waste processing (%)		0	0	+50	+70
Freight Percentage (%)	Truck	10	0	-10	-10
	Pick up	30	+10	+5	0
	Motorcycle	60	-10	+5	+10
Numb. of Transportations (Unit)	Truck	1	1	-1	-1
	Pick up	2	2	+1	+2
	Motorcycle	55	-5	-10	-10

Information: -00: decrease of 00 from the basic scenario; +00: increase of 00 from the basic scenario.

Table 5: GSCM performance index in the basic scenario.

Criteria	Weight (%), total amount = 1	Basic scenario			
		Simulation Value 2023*	Weight x Simulation Value	Simulation Value 2035*	Weight x Simulation Value
1. The amount of solid waste produced	0.080	50.00	3.99	50.00	3.99
2. % of solid waste recycled	0.026	66.67	1.76	66.67	1.76
3. The amount of liquid waste produced	0.065	33.33	2.16	33.33	2.16
4. % of liquid waste recycled	0.022	0.00	0.00	0.00	0.00
5. Potential CO_2 emissions Eq	0.168	100.00	16.78	81.47	13.67
6. Cycle time	0.154	2.73	0.42	77.19	11.92
7. % stockout	0.038	100.00	3.75	41.73	1.57
8. % safety stock	0.057	4.30	0.24	0.00	0.00
9. % Fulfillment of fertilizer needs with alternative fertilizers	0.037	44.98	1.65	100.00	3.67
10. Production costs (Rp/kg green beans)	0.140	6.53	0.92	65.42	9.17
11. Profit margins	0.137	26.08	3.58	43.20	5.93
12. Average inventory amount	0.053	3.07	0.16	0.00	0.00
13. Number of alternative fertilizers and solid waste sold	0.024	0.00	0.00	41.91	0.99
Performance index			35.40		54.81

*Snorm de Boer scale.

Based on the basic conditions above, the modeler changes the values of the desired parameters. Changes in these parameters can be the basis for decision-making and can be a future picture of how the GSCM performance of Argopuro smallholder robusta coffee plantation in Jember Regency will be. Changes in parameter values for each scenario will be compared and seen at the end of the simulation year. The GSCM performance index with scenario is presented in Table 6.

4 DISCUSSIONS

The system dynamic model for measuring GSCM performance at UPH Sumber Kembang succeeded in simulating system behavior quite well as indicated by a MAPE value of 12%. Based on the results of the model simulation before the scenario intervention, the GSCM performance index value was only 35.40 (good enough), basically insufficient. The basic condition is a condition where there is no change in the scenario parameter values. Many environmental indicators have low value, such as indicators for the amount of liquid waste, the proportion of liquid waste recycling, and the use of organic fertilizer. Except for the CO_2 emission indicator which has a high value, this means that the level of air pollution at UPH Sumber Kembang is still low. Meanwhile, many indicators that show business operational performance also have low value, for example cycle time, safety stock, average inventory and production costs. The low value of business operational performance indicators is caused by low profits so that there is not enough incentive to improve workforce skills. Low skills apparently also contribute to the low value of environmental performance indicators.

This condition occurs because the workforce's skills are still low and there has been no effort by UPH to process liquid and solid waste. If explored further, the value of this workforce skill indicator is related to the business profit variable. Increasing profits will increase incentives for workers so that skills will increase. The low value of UPH profits in 2023 is due to the relatively small amount of coffee harvested. The variable number of coffee harvests greatly influences the performance of other system components, because the variable number of coffee harvests will determine whether the amount of coffee produced will be processed or not. According to Kath et al. (2021), rainfall is a variable that greatly influences the growth of coffee plants, thereby influencing the value of harvest productivity. As coffee productivity increases, the number of coffee fruit harvests also increases.

In 2023, the coffee harvest will only reach around 146 tons from a land area of 150 ha. This small production amount has an impact on increasing the performance of the potential CO_2 Equivalent emission variable which gets a value of 100 (maximum). Maximum value results from reducing fuel use for both transportation and production machines. Following the statement of Osobajo et al. (2020) agro-industrial activities have a negative impact, namely the emergence of emissions resulting from the use of fuel for machines and transportation. The greater the emission value, the lower the performance in the environmental dimension.

Table 6: GSCM performance index using scenario.

Criteria	Pessimistic		Moderate		Optimistic	
	Simulation Value 2023*	Weight x Simulation Value	Simulation Value 2035	Weight x Simulation Value	Simulation Value 2035*	Weight x Simulation Value
1. The amount of solid waste produced	50.00	3.99	50.00	3.99	50.00	3.99
2. % of solid waste recycled	33.33	0.88	83.33	2.19	100.00	2.63
3. The amount of liquid waste produced	33.33	2.16	33.33	2.16	33.33	2.16
4. % of liquid waste recycled	0.00	0.00	50.00	1.10	90.00	1.98
5. Potential CO_2 emissions Eq	91.55	15.36	93.83	15.74	81.14	13.61
6. Cycle time	68.02	10.51	68.42	10.57	80.90	12.49
7. % stockout	0.00	0.00	67.36	2.53	100.00	3.75
8. % safety stock	0.00	0.00	0.00	0.00	100.00	5.66
9. % Fulfillment of fertilizer needs with alternative fertilizers	80.82	2.97	100.00	3.67	100.00	3.67
10. Production costs (Rp/kg green beans)	58.24	8.16	58.54	8.20	68.49	9.60
11. Profit margins	37.53	5.15	37.77	5.18	45.62	6.26
12. Average inventory amount	0.00	0.00	1.26	0.07	8.67	0.46
13. Number of alternative fertilizers and solid waste sold	0.00	0.00	29.19	0.69	100.00	2.36
Performance index		49.16		56.09		68.62

*Snorm de Boer scale.

When the model simulation was continued until 2035, the GSCM performance index value increased to 54.81 (good). The increasing behavior of coffee fruit production from year to year has led to an increase in processed coffee production. This increase was influenced by increased productivity which had an impact on the amount of coffee harvest produced, namely 327.51 tons. Productivity is influenced by rainfall variables (Kath et al., 2021). The difference in productivity is due to changes in rainfall values due to the random number generator every time the simulation is run. This will have an impact on increasing UPH profits. Increasing profits ultimately improves workforce skills. This is what causes the improvement in the value of business operational performance indicators, and some environmental indicators, namely the use of organic fertilizer and fertilizer sales. This is because there is a positive relationship between workforce skills and these indicators. However, increasing the amount of production also has an impact on increasing the use of engine fuel and transportation. This condition causes the performance of the potential CO_2 Equivalent emission variable to get a value of 81.47.

To increase the GSCM index value, a number of scenarios were applied (Table 4). Election Policy variables are based on model simulation results. The model simulation results show 2 important things that need to be done. The first is how liquid and solid waste processing at UPH can be improved to achieve environmental indicators related to this could be better. The second is how to improve workforce skills because improving these skills is closely related to many indicators of business operational performance and environment. For this reason, policy variables emerged as shown in the table. Increasing the proportion of liquid and solid waste processing will directly increase the value of this indicator. Meanwhile, regulating the type and number of transport fleets will have an impact on production cost efficiency. Reducing production costs will increase business profits and ultimately improve workforce skills. Changes in these parameters can be the basis for decision making and become a future picture of how the GSCM performance of Argopuro smallholder Robusta coffee plantations will be. Changes in parameter values for each scenario will be compared and seen at the end of the simulation year.

In the pessimistic scenario, the GSCM performance value is 49.16. This is due to a decrease in the performance value of the variable percentage of solid waste recycled where only 50% of the waste is processed. This variable affects reducing the percentage of fulfilling fertilizer needs with alternative fertilizers and the absence of income from selling compost. The total coffee harvest was 257.88 tons and this affected the performance of other components.

In the moderate scenario, the GSCM performance value is 56.09. The parameters that have increased are the percentage of solid waste recycled by 80% and the percentage of liquid waste recycled by 50%. These two parameters influence GSCM performance to be better even though the other parameters experience dynamics due to changes in the value of the coffee harvest. The total coffee harvest was 260.25 tons which was influenced by productivity due to rainfall (Kath et al., 2021).

The GSCM performance value in the optimistic scenario is 68.62. This scenario can improve most performance indicators, especially those that focus on the environment, namely the percentage of solid waste recycled (90%), the percentage of liquid waste recycled (70%), and changes in the combination of fleets used. Increasing the percentage of waste being processed has an impact on fulfilling fertilizer needs independently as well as earning income from the sale of compost fertilizer.

The variable amount of coffee harvest which is influenced by productivity due to rainfall has an impact on performance indicators that focus on operations and business only. Meanwhile, an optimistic scenario by providing interventions to change the value of indicators that focus on the environment can influence GSCM performance for the better even though other parameters experience dynamics due to changes in the value of the number of coffee harvests. The variables in the optimistic scenario can be operationalized by the manager. So, the next stage is that the modeler provides policy recommendations for managers so that optimistic scenarios can be implemented.

The indicator of success in implementing GSCM for Argopuro smallholder robusta coffee plantation boils down to the resulting performance value. The best policy and action recommendations are the results of a simulation of an optimistic scenario (SR3), which is influenced by the parameters of increasing liquid waste processed by biogas, increasing solid waste processed by compost, and adjusting the number of fleets. These parameter changes were able to improve the GSCM performance of Argopuro smallholder robusta coffee plantation, Jember Regency.

Reducing the amount of solid and liquid waste by processing it into compost and biogas has a positive impact on the environment. Compost can also be sold, becoming a new source of income for farming groups. Meanwhile, biogas can be used as a new energy source and reduce dependence on the use of petroleum fuels. The recommendations that can be given to reduce coffee processing waste are as follows.

1. Providing outreach and education to farmers regarding (a) the impact of waste produced on the environment, (b) the use of waste can increase added value and the community's economy, and (c) providing an overview of the potential for changes in consumer preferences regarding product purchasing decisions which are environmentally friendly.
2. Provide technical guidance and assistance to farmers regarding how to convert solid coffee waste into compost and liquid waste into biogas.
3. Processing solid waste into compost can be done by making compost plots or by using tarpaulins on unused land (Ningrum; Pramitasari; Kartini, 2023).
4. Building a reactor unit for processing liquid waste into biogas. According to Novita et al. (2023), construction of one biogas reactor unit costs an investment of IDR 7,208,000 which can accommodate 14.13 m^3 of liquid waste produced.

Apart from the method above, potential emissions can be reduced by replacing the truck transport fleet which previously used 1 unit by adding 2 pickup fleets. Apart from that, the number of motorbike fleets which previously used 55 units was reduced to 45 units. Even though the fleet used has changed in combination with its initial condition, it can still accommodate the delivery of coffee raw materials from the field to the UPH. Based on the simulation results, changing this combination can reduce the amount of fuel used and have an impact on the emissions produced.

5 CONCLUSIONS

The system dynamic model that has been built can describe the system behavior quite well. The model also succeeded in predicting the values of 13 key performance indicators (KPI) to obtain the GSCM performance index value. The simulation results in 2023 before implementing the scenario show an index value that is classified as good enough (35.40). The majority of indicator values are low due to 2 main things, namely UPH Sumber Kembang has not optimally processed liquid and solid waste, and low workforce skill values. If the simulation is continued until 2035, the performance index value increases significantly and is categorized as good (54.81). This is due to an increase in coffee fruit production over time due to increased harvest productivity. This condition will have an impact on increasing business profits. In the end, increasing business profits will have an effect on increasing incentives and workforce skills. The skill variable is a very important system variable because increasing the value of this indicator has an effect on increasing production yield, harvest productivity and the amount of liquid waste.

Increasing the value of the GSCM performance index is carried out through the application of policy scenarios, namely by changing the values of policy parameters which have a major influence on increasing the value of environmental performance indicators and business operational indicators. The selected policy parameters are efforts to improve liquid and solid waste processing, and regulation of the number and type of fleet. The application of the policy scenario can increase the value of the GSCM index, but the application of the optimistic scenario gives the best results, namely obtaining a value of up to 68.62 (Good) in 2035. This scenario is built by providing intervention to increase the percentage of waste processing by 90% for solid waste and 70% for liquid waste. Increase the number of pickup fleets to 4 units and reduce the motorbike fleet by 45 units to be more optimal and reduce the amount of emissions produced. Although the optimistic scenario can increase the GSCM index value compared to basic conditions, in general the increase is not significant because it is still in good status.

The implementation of the optimistic scenario is to utilize liquid and solid waste into compost and biogas to reduce environmental emissions and reduce production costs. Arranging the number and type of fleet as in this scenario can significantly reduce the emission burden and increase business profits.

6 AUTHORS' CONTRIBUTION

Conceptual Idea Purnomo, B.H., Methodology design Purnomo, B.H; Wibowo, Y. Data collection Ni'maturrakhmat, V.N., Data analysis and interpretation Purnomo, B.H; Ni'maturrakhmat, V.N.; Wibowo, Y., Writing and editing Purnomo, B.H.; Ni'maturrakhmat, V.N.

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