International Journal on Advanced Science Engineering Information Technology

Vol.9 (2019) No. 6
ISSN: 2088-5334

# Supply Chain Performance Measurement Model of Passion Fruit Agro-Industry for Sustainable Micro, Small, and Medium Enterprises with System Dynamics in North Sumatra Province

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***Abstract*— Supply chain management covers integrated activities of planning, coordinating, and controlling of all business processes and practices in the supply chain to meet the demands of consumers at the lowest possible cost. Sustainable supply chain can be achieved by taking into account three pillars of sustainable development, namely, economy, social, and environment. Passion fruit agro-industry supply chain actors consist of farmers, collectors, agro-industries, and retailers. This study aims at identifying factors affecting the passion fruit agro-industry supply chain performance for sustainable micro, small, and medium enterprises and designing a supply chain performance measurement model of MSME passion fruit agro-industry with system dynamics. This research used a survey method through observations, in-depth interviews, and expert opinions. Data were processed using a combination of the hard system (system dynamics analysis) and soft system (expert opinions).The feedback structure along the passion fruit syrup agro-industry system was modeled in a causal loop diagram using system dynamics through version 10 of Powersim Studio software. It was then translated into a stock-flow diagram as the implementation of the simulation model. The model was verified using a computerized statistical analysis (Absolute Means Error) technique. To formulate recommendations and development strategy scenarios for sustainable MSME passion fruit agro-industry supply chain, a system approach method was used and expected to produce an effective and operational decision in accordance with the objectives previously set. The results obtained through expert opinions and Analytic Hierarchy Process (AHP) which have the highest weight with various conditions for each variable. Seven key variables were proven to influence the performance of passion fruit agro-industry supply chain, which were also used to design a sustainable MSME supply chain development scenario. The behavior of the sustainable passion fruit agro-industry supply chain model took the form of positive growth and the error rate of 7.43. Developing a sustainable MSMEPFASCPM can be carried out with a moderate strategy by developing: 1) pattern of good relationships among the actors, 2) gradual increase in the availability of raw materials, 3) environmental support capability, 4) gradual increase of profits, 5) moderate skills, 6) employment opportunities, and 7) land availability.**

***Keywords*— supply chain; system dynamics; sustainable; agro-industry.**

## I. INTRODUCTION

In this era of globalization, many new emerging companies operate in similar industries, which will lead to increasingly fierce business competition. Currently, business competition is unlike any ordinary competition; it has reached to the competition among supply chains by providing more added value to the products and services. Providing product and services as the customer demanded is the main goal in achieving customer satisfaction. The timeliness of delivery in the production process is one of the main factors in obtaining orders from customers and creating customer loyalty. These activities cannot be separated from the supply chain concept, where the process of procuring, processing, and shipping products to customers is a sequence of processes and business activities involving a number of parties ranging from suppliers to customers. Industry players understand that providing cheap and high-quality products and services as fast as possible cannot be performed by internal improvements of the manufacturing company alone. These three aspects require the participation of all parties from suppliers of raw materials, factories that process raw materials into semi-finished materials and finished products, transportation companies that send products to retailers and distribution networks that deliver products to customers. The importance of all participation in providing inexpensive, high quality, and fast products has created a new concept of supply chain management in the early 1990s. The concept of supply chain management integrates various management functions within an organization as an integrated and supportive system. The key to effective supply chain management is to make the suppliers as "partners" in the company strategy to fulfill the ever-changing market [1].

Supply chain management is the integration of planning, coordinating, and controlling of all business processes and activities in the supply chain to meet the demands of consumers at the lowest possible cost [2].

In this study, the author focuses on one of the MSME agro-industry products of passion fruit (*Passifloraceae*). The Karo District is chosen as a place to test the model, for it is the main producer of fruits, vegetables, and flowers to North Sumatra Province because of its specific climate and fertile soil. This supply chain design is very useful for a sustainable MSMEPFASC, shown through the analysis of sustainable indicators that are based on economic, social, and environmental aspects that are formed into a sustainable system design. The main actors (internal actors) involved in the passion fruit supply chain that can determine effective, efficient, and responsive policy alternatives in the development of sustainable passion fruit supply chains are farmers, collectors, agro-industries, and retailers.

Specifically, researches on agricultural sustainable supply chains which address economic, social, and environmental aspects are still very limited, among others are those carried out by [3]–[8]while [9]–[14] are researches on non-agricultural (manufacturing) commodities.

From a preliminary survey in Karo District, it was derived that the development of the passion fruit agro-industry supply chain performance has not reflected a sustainable aspect because several problems have been found to date, among others: 1) fulfillment of the quantity and time-delivery of raw materials; 2) the risk management ability of actors in a supply chain, 3) the inefficient management of byproduct (pulp) and the high usage of non-organic fertilizers in the production system, 4) the pattern of linkages among the actors that has not resulted in an expected condition (still fragmented), 5) prices received by farmers and collectors are not fair enough compared to agro-industry especially during the harvest time, where farmers and collectors carry more risks than the agro-industries, 6) activities are still limited, referred to as trade systems (no supply chain yet), 7) fluctuating demand, 8) the unpredictable availability of raw materials, and 9) suboptimal management of physical, information, and capital flows caused by the lack of coordination among supply chain actors. The current MSME agro-industry management practices are still partial and no attention has been paid to good relations among supply chain actors. Some of the above problems have led to an inefficient and ineffective sustainable MSME agro-industry supply chain performance, which in turn can increase supply chain costs and causes distortion of raw material and product inventories at the consumer level.

Looking at the above issues, it is necessary to conduct a comprehensive study by building a supply chain model of sustainable MSME agro-industry, which in its testing uses the passion fruit business. In designing the model, it is necessary to pay attention to the characteristics of agro-industrial products which differ from non-agro-industrial products. After the model was designed, the next stage was to simulate the sustainable MSME agro-industry supply chain using system dynamics to understand the symptoms or processes that support the various decisions taken. The aim of this study is to identify affecting factors, to design a measurement model, and to carry out a simulation of the passion fruit agro-industry supply chain performance for sustainable MSME with system dynamics.

## II. Material and Method

This research used a survey method through observations, in-depth interviews, and expert opinions with a causal descriptive approach. It aims to describe and analyze the relationship between variables systematically, factually and accurately about the facts and the nature of an object or population. The system approach is used to formulate strategies and recommendations for the supply chain performance of sustainable micro, small, and medium enterprises passion fruit agro-industry.

The study begins with the identification of variables influencing the supply chain performance of sustainable micro, small, and medium enterprises of passion fruit agro-industry using in-depth interview technique to experts. The data is then analyzed using Analytical Hierarchy Process (AHP) to determine dominant indicators influencing passion fruit agro-industry supply chain performance on current conditions, which are then used as important (indicators) in the system. Following this, the level of influence and dependence among these factors are analyzed. In the next stage, an analysis of the needs of all stakeholders concerned with the system is carried out so that important indicators in building a sustainable MSME passion fruit agro-industry supply chain performance model are obtained. The model built refers only to quantitative variables using system dynamics analysis to observe the dynamics between factors and model (system) behavior using Powersim Studio 10 software. In the final stage, recommendations and development strategies for sustainable MSMEPFASC are formulated. The whole research framework can be seen in Figure 1. Based on the research framework, data processing is carried out through stages: 1) analysis of variables (indicators) that continuously affect the performance of MSMEPFASC, 2) design of a sustainable MSMEPFASC model, 3) sustainable MSMEPFASC model simulation, 4) validation of the sustainable MSMEPFASC model, and 5) preparation of sustainable MSMEPFASC recommendations and strategies. The stages of research can be seen in Figure 2

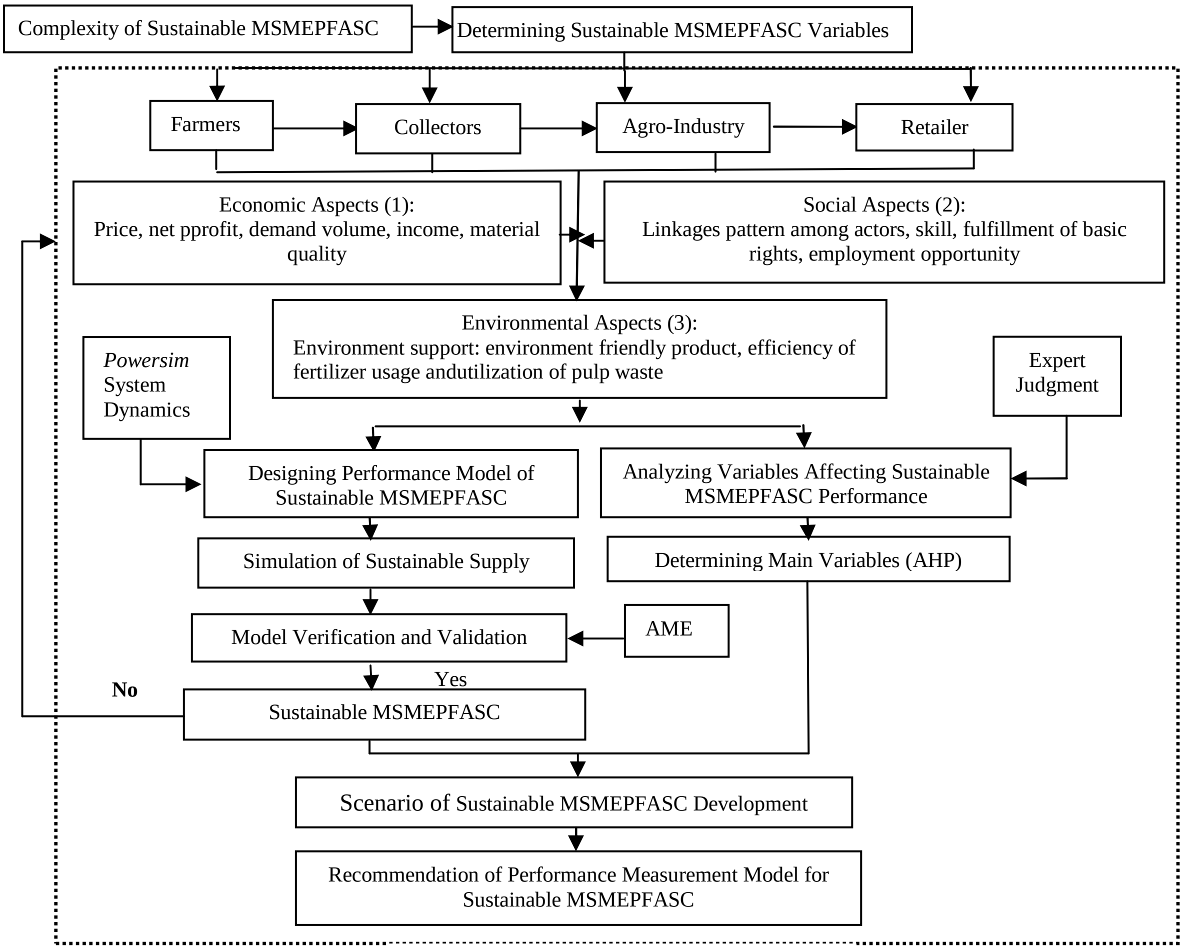


Fig. 1 Research framework

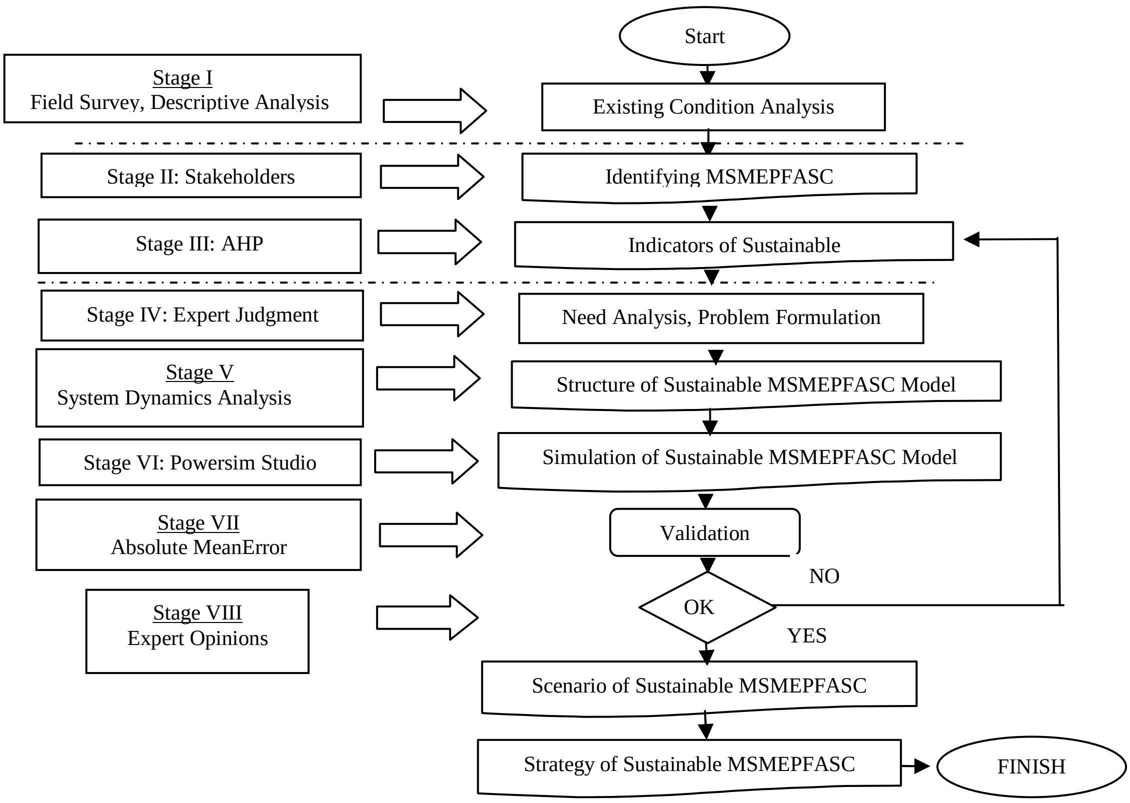


Fig. 2 Research stages

## III. Results and Discussion

### A. *Identification of Factors Affecting Sustainable MSMEPFASC*

Operationally, the supply chain sustainability system of RPGBKG has a complexity because it involves several actors and activities that normally have their own interests. In connection with the research carried out, the complexity could be seen in the determination of variables that reflect sustainability aspects of RPGBKG. In this study, the process of determining sustainability variables was done based on the literature review relevant to the substance of the research.

TABLE I
ANALYSIS RESULTS OF SUSTAINABLE MSMEPFASC INDICATORS

| No | Aspect | Variable | Weight |
|---|---|---|---|
| 1 | Econom y | 1. Price | 0.1477 |
| | | 2. Income | 0.1583 |
| | | 3. Demand Volume | 0.0901 |
| | | 4. Availability of Raw Materials | 0.2658* |
| | | 5. Net Profit | 0.2380 |
| | | 6. Material Quality | 0.1001 |
| 2 | Social | 7. Worker Skill | 0.2258 |
| | | 8. Employment Opportunity | 0.2203 |
| | | 9. Fulfillment of Basic Rights | 0.1946 |
| | | 10. Pattern of Interdependency Relationship | 0.3593* |
| 3 | Environ ment | 11. Land Availability | 0.2015 |
| | | 12. Amount of Waste | 0.1506 |
| | | 13. Amount of Compost | 0.1054 |
| | | 14. Environmentally Friendly Products | 0.1828 |
| | | 15. Environmental Support Capability | 0.2462* |
| | | 16. Fertilizer Efficiency | 0.1136 |

The results of the literature review were discussed with several experts who have the capability of the passion fruit business process. As a system, the performance of sustainable MSMEPFASC is strategic, complex, dynamic, and cross-sectoral. For this reason, it is necessary to identify and analyze the factors that affect the sustainable MSMEPFASC performance system. The results of discussions and interviews with experts then obtained sixteen variables that affect the performance of MSMEPFASC and the weighting results, which can be seen in Table 1.

The identification analysis results of sustainable MSMEPFASC performance variables (Table 1) show that the pattern of interdependency relationship variable (social aspect) had the highest weight (0.3593) among all variables. The availability of raw materials variable (economic aspect) then followed with the weight of 0.2658 reaching the second highest. Furthermore, the environmental support capability variable (environmental aspect) with the weight of 0.2462 was on the third highest. In this case, the pattern of interdependency relationship between actors had greatly affected the sustainability of the passion fruit agro-industry supply chain system and had become the concern of supply chain actors. Culturally, the main actors in the MSMEPFASC system are the people of Karo ethnicity who have a local wisdom towards the fellow business people, in this case a social bond between actors.

### B. *System Identification*

The concept of system identification is a chain of relationships among statements of needs with specific statements of problems to be resolved to meet those needs [15], which are often shown in the form of causal loop diagrams for designing models of the system. System identification aims at providing an overview of the MSMEPFASC sustainability system in the form of causal loop diagrams as shown in Figure 3, which is then translated into input-output diagrams as shown in Figure 4. In Figure 3, there are 1 reinforcement loops (+) covering the performance of sustainable MSME passion fruit agro-industry supply chain. This means that the simulation result also resembles a loop (+) pattern on a causal loop diagram (CLD).

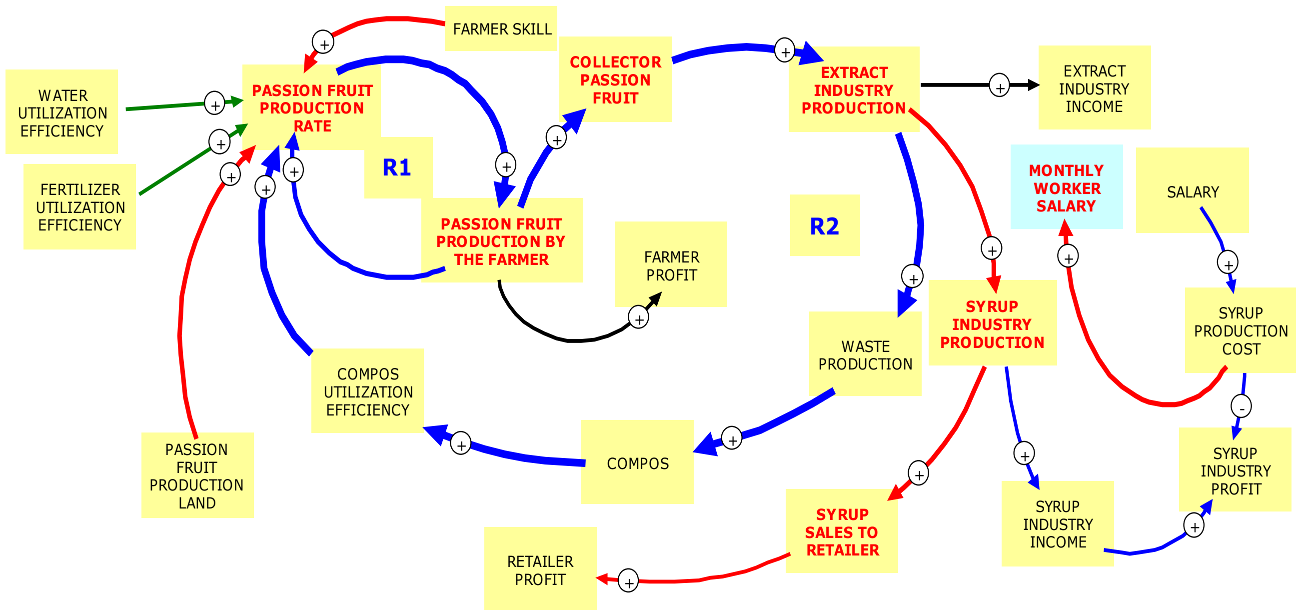


Fig. 3. Causal Loop Diagram

Loop R1is in the form of reinforcing (positive feedback loop) characterized by growth, where the high passion fruit production at the farmer level will affect the rate of passion fruit production. The rate of passion fruit production is also influenced by the farmer skill. In loop R2, the rate of farmer profit affects the rate of their welfare. The rate of farmer welfare affects the passion fruit production by the farmer. The higher the passion fruit production by the farmer is, the higher the rate of their profit becomes. This loop R2 is also in the form of reinforcing (positive feedback loop) characterized by growth. In loop R3, the higher the passion fruit production by farmer is, the higher the rate of the collector passion fruit becomes. The increased collector passion fruit also increases the extract industry production. The increased extract industry production increases the waste production, which then can be used as compost for sale to farmers. The higher the compost production is, the higher the compost utilization efficiency becomes, which in turn can produce environmentally friendly products. Consequently, the environmental support capability increases. The increased environmental support capability then affects the passion fruit production land. Eventually, the passion fruit production land influences the rate of passion fruit production.

### C. *Sustainable MSMEPFASC Modeling*

The sustainable MSMEPFASC stock-flow diagram (model structure) was based on causal loop diagrams in such a way as to mimic the actual condition of the MSMEPFASC by taking into account the determinant (highest weight) indicators obtained from AHP weighting results. It was built by employing the system dynamics through Powersim Studio version 10 software. The sustainable MSMEPFASC stock-flow diagram is shown in Figure 4.

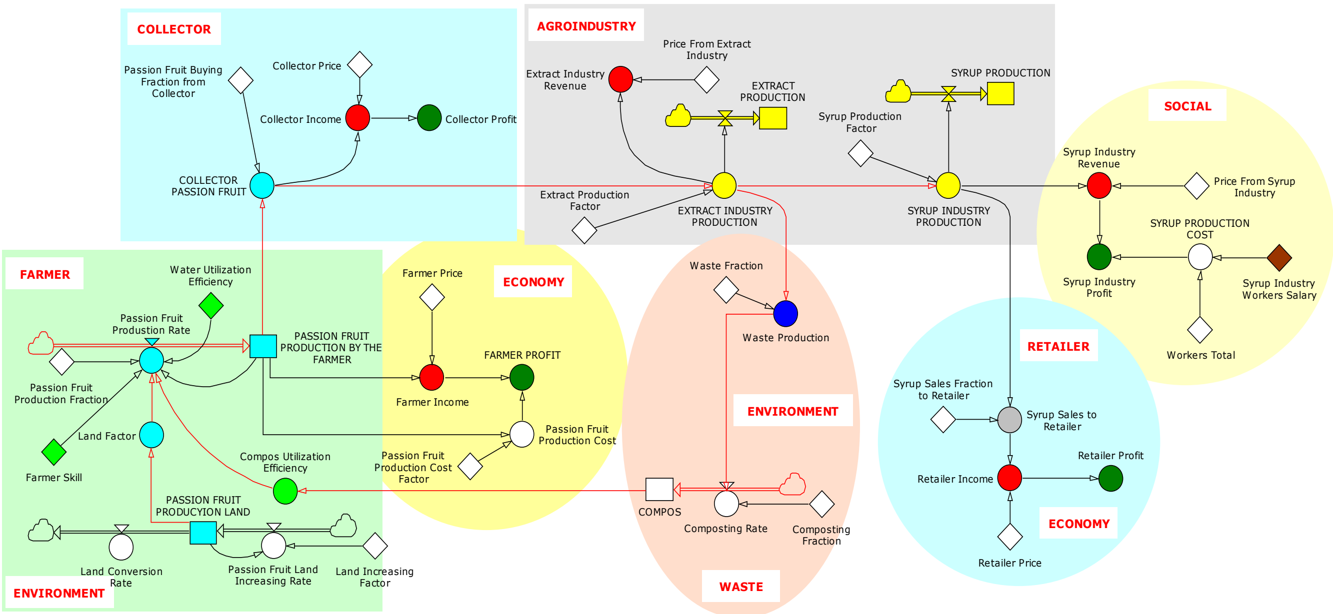


Fig. 4. MSMEPFASC Model Structure

The model structure of this sustainable MSMEPFASC was built by adopting a sustainable building concept consisting of 3 aspects; economic, social, and environmental aspects. Several actors who are the key roles in this case are farmers, collectors, agro-industries, and retailers. In Figure 4, the economic aspects are represented by variables of price, net profit, income, demand volume, availability of raw materials, and material quality from the actors (farmers, collectors, agro-industries, and retailers). Social aspects are illustrated by variables of pattern of interdependency relationship between actors, worker skill, employment opportunity, and fulfillment of basic rights. Besides, environmental aspects are represented by land availability, environmental support capability, amount of waste, fertilizer efficiency, amount of compost as well as environmentally friendly products. Each aspect has its own relationship pattern.

### D. *Supply Chain Simulation of Sustainable MSME Passion Fruit Agro-industry*

After the model was designed, then the next step was to simulate it using a software that can quickly identify the model's behavior, namely Powersim Studio 10. Simulation is the imitation of the behavior of a symptom or process. It aims at understanding the symptoms or processes, analyzing them and predicting their behavior in a certain time frame in the future [15]. Powersim Studio 10 was used to build and simulate a model of system dynamics. The basic characteristic in system dynamics simulation is applying quantitative variables, which in this study are variables of passion fruit production in simulated farmers.) In the simulation stage, one of the variables affecting the performance of a sustainable MSMEPFASC, which is passion fruit production at the farmer level, was chosen. The simulation shows that the behavior is in the form of growth. Figure 6 shows that the model structure pattern creates reinforcement model behavior.

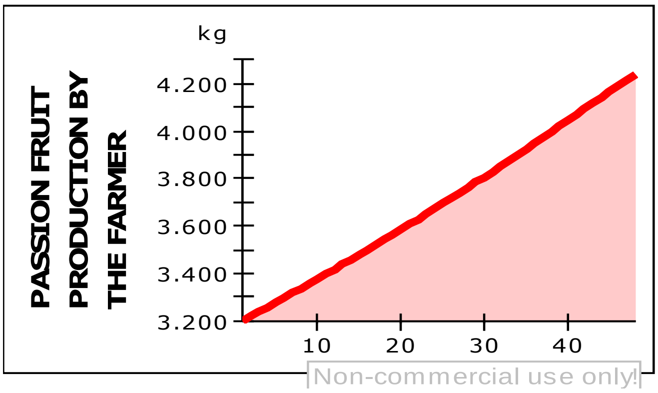

Fig. 5 Farmer Production Simulation

### E. *Sustainable MSMEPFASC Scenarios*

Based on the state of each factor (variable) in Table 2, various strategic scenarios are formulated by pairing the changes that will occur and analyzing their implications for the system. The selected scenario is a moderate scenario by developing: 1) pattern of good relationships among the actors, 2) gradual increase in the availability of raw materials, 3) environmental support capability, 4) gradual increase of profits, 5) moderate skills, 6) employment opportunities, and 7) land availability.

## IV. Conclusions

To improve the performance of sustainable MSME passion fruit agro-industry supply chain development, 7 factors were obtained: a) economic aspect (profit and availability of raw materials), b) environmental aspects (environmental support capability and land availability), c) social aspects (relationship patterns among actors, skills, and employment opportunities). There are seven factors influencing the performance of the sustainable MSME passion fruit agro-industry supply chain: a) economic aspects (net profit and availability of raw materials), b) environmental aspects (environmental support capacity and land availability), c) social aspects (pattern of interdependency relationship, worker skill, and employment opportunity).

The behavior of developing sustainable MSME passion fruit agro-industry supply chain performance is obtained through system dynamics analysis simulation in the form of growth (reinforcement) for all three aspects (economy, social, and environment). This behavior illustrates that there is a growth for the production and income of farmers; and the production of essence and syrup. The model structure of the sustainable MSMEPFASC was built by adopting the concept of sustainable development consisting of three aspects; economic, social, and environmental aspects and several actors who have key roles: farmers, collectors, agro-industries, and retailers. Economic aspects are represented by variables of price, net profit, income, demand volume, availability of raw materials, and material quality from actors (farmers, collectors, agro-industries, and retailers). Social aspects are described by variables of pattern of interdependency relationship, worker skill, employment opportunity, and fulfillment of basic rights, while environmental aspects are land availability, environmental support capability, amount of waste, fertilizer efficiency, amount of compost, and environmentally friendly products. Each aspect has a relationship pattern with each sub-system.

Model simulation generated the behavior of sustainable MSME passion fruit agro-industry supply chain performance with system dynamics in the form of growth.

The most realistic scenario is the moderate scenario because future conditions that might occur are taken into account in full accordance with the conditions and capabilities of the obtained resources. This scenario also confirms that passion fruit agro-industry supply chain business activities can provide reasonable benefits for each passion fruit agro-industry supply chain actor and contribute to regional economic growth.

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