ATLANTIS PRESS
Advances in Economics, Business and Management Research, volume 100
International Conference of Organizational Innovation (ICOI 2019)

DESIGN OF CIRCULAR SUPPLY CHAIN AGENT-BASED MODEL: CASE OF ORGANIC FERTILIZER PRODUCER

Ruth Nattassha (School of Business and Management, Institut Teknologi Bandung, Indonesia)
Togar M. Simatupang(School of Business and Management, Institut Teknologi Bandung, Indonesia)
Yuanita Handayati (School of Business and Management, Institut Teknologi Bandung, Indonesia)

Email: ruth_nattassha@sbm-itb.ac.id

Abstract—One of the most important issues in agri-food industry and its supply chain is the existence of by-products, treated as wastes and discarded immediately to the waste disposal. This treatment might lead to loss of possibility in gaining economy value from them. Implementation of circular economy concepts could prevent the economy value loss, through utilization of said wastes as resources for other processes. While it has high opportunity in Indonesia, the implementation has met several obstacles, especially in the case of an organic fertilizer producer which operates with organic wastes as their inputs. In this research, the agent-based model of the company's case is defined, along with the issues they met. The model is expected to be used as testing ground for various scenarios to be taken by the company in marketing and selling their products.

Keywords— circular economy, agent-based, supply chain, organic fertilizer.

I. INTRODUCTION

The agri-food industry is one of the most important industries related to human welfare as it is the industry which is directly related to the procurement of humans' basic need: food. The industry itself has been growing along with the development of civilization, as well as several issues arising in the industry. One of them is the high amount of waste from this industry, resulted from various processes conducted to produce the food products (Paloviita, 2017). This issue has also been acknowledged as one of the characteristics in the supply chain of the agri-food industry, in which, generally, only one or two results from the processes are considered as the product, while the other inevitable by-products are viewed as wastes (Van der Vorst et al., 2005). These wastes are often discarded directly to the waste disposal, resulting in the failure to gain economic value from the by-products.

The loss of economic value from by-products of agri-food processes can be avoided by implementing the concepts of circular economy. The circular economy, first suggested by Pearce and Turner (1989) and then further expanded by EM Foundation (2012) is an economy system in which the wastes of one process are not discarded directly, but, instead, become the resources for other processes. These other processes will, in return, provide possible resources for the original process. The workflow of this system is designed to mirror the living system, which is said to be feedback-rich.

Through the implementation of this circular economy concept, there is possibility of gaining economic value from many by-products in the agri-food industry. There is also an opportunity for this implementation to be conducted in Indonesia. As recorded by Badan Pusat Statistik (2017), in Jakarta alone there is up to 3,233 cubic meters of organic waste, most of which has resulted from the activities in the agri-food industry. Some of this organic waste actually can be used as resources for other processes, which, in turn, will provide resources for the agri-food activities.

OrganicFe Co., an organic fertilizer producer based in Bekasi, Indonesia, is a company operating based on said principles. With the input resources of organic wastes, mainly composed of vegetable and fruit wastes, they can produce organic fertilizer and livestock feed by utilizing the black soldier fly larvae. The larvae consume vegetable and fruit wastes, then their biological wastes will be processed to become organic fertilizer. The larvae later can also be processed to become fish and livestock feeding. As they utilize the wastes from other agri-food supply chains and provide resources for said supply chain, it can be said that OrganicFe Co. is a key actor for implementation of circular economy concepts in the Indonesian agri-food supply chain.

However, OrganicFe Co. encountered problems in their interaction with farmers as their customers. This is mainly caused by the variety of farmers' characteristics and behavior: while some farmers purchase the fertilizer, others distrust organic fertilizer in general, some are opportunistic and only want free fertilizer, and there are also others who have high pride and will not try the fertilizer if their neighbor already uses it. Another problem arose from the farmers' side, in which, apparently, OrganicFe Co. does not have enough knowledge in actual farming, as they lack several steps in the procedure of applying their fertilizer or do not know the quality characteristics of plant farmers' needs.

The case of OrganicFe Co. demonstrates that the variety of behavior from one type of agent in the system can affect the outcome of the system, which, in this case, is the sales numbers of OrganicFe Co.'s organic fertilizer. In this research, we would like to analyze the problem from the perspective of agent-based model method framework. The agent-based model method is a modeling paradigm in which the behavior of a system's participants (agents) can be modelled, whereby the interaction between these agents and each of their behaviors result in something observable; this is also known as the emergent properties of the system (Wilensky & Rand, 2015). In this method, the various behaviors of participants within a complex system can be addressed (North et al., 2005). The agent-based model has been used as the social aspects of models due to its ability to simulate behavior of agents and interaction between them, such as in the research by Daloğlu et al. (2014) in which farmer agents are defined by their types and characteristics. When farmers with certain characteristics are affected by certain agricultural policies, they will react by choosing a certain conservation practices. The result of this interaction will then affect another linked model, the soil and water assessment model. So, from this model, the observable variables or the emergent properties are the soil and water quality, which are affected by the conservation practices adopted by the farmers.

In this research, the framework of agent-based model is used to analyze and define the current situation of OrganicFe Co.'s problem. Interviews with both the OrganicFe Co.'s side and the farmers' side were conducted, resulting in a description of the problem and definition of agents and workflow for OrganicFe Co.'s interaction with the farmers. In this research, the design is focused on OrganicFe Co. and the farmers. Several suggestions as to OrganicFe Co.'s current workflow are also defined, which mostly come from discussion with researchers from the farmers' side and theories from previous literatures. The emergent property to be observed in this model is OrganicFe Co.'s fertilizer sales, affected by the farmers' interaction and behavior.

II. LITERATURE REVIEW

As previously mentioned, circular economy is mostly concerned of the utilization of wastes as resources for other processes. According to EM Foundation (2012), the workflow of a circular economy is divided into two cycles: the biological cycle and technical cycle. In the biological cycle, the wastes will go through extraction of biochemical feedstock, anaerobic digestion and composting, before being returned to the biosphere and becoming biological nutrients. Meanwhile, for the wastes in technical cycles, they will go through the recycle, refurbish, reuse, or maintenance processes before they become technical nutrients for the main system workflow. Wastes in agri-food industry generally go through the biological cycle.

One of the most important properties of a circular economy is the existence of various processes, in which the wastes of one process will become the resources for another and so on. There is also the possibility that these processes are conducted by more than one actor, resulting in the interaction between the actors. Thus, when developing a model for such system, it is necessary to use a methodology which allows the involvement of more than one process as well as more than one actor. North et al. (2005) mentioned that the agent-based model can include the various behaviors of the actors, and Nilsson and Darley (2006) further confirmed this by the utilization of agent-based model for aiding the decision-making process in a packaging company.

Utilization of the agent-based model can also be observed in the research of Daloğlu et al. (2014) which involved several types of farmers with different characteristics and behavior. These characteristics and behavior are related to the way they react to various agriculture policies, and this reaction will result in their decision in adopting one particular conservation practice. The agent-based model is linked to the water quality model, so the conservation practices adopted by various farmers have effects on soil and water quality. With this model, the effect of policies towards soil and water quality can be observed.

There are several existing researches concerning the relation between marketing strategy and customers' behavior. Rahbar and Abdul Wahid (2011) found that some green marketing tools have an effect on consumers' purchase behavior. Jiuan Tan (1999) found that there are several strategies that can be used to become risk relievers for potential customers of Internet shopping. In the Verhoef et al. (2010) model, customer characteristics are also a factor to affect customer engagement strategies.

III. METHOD

As in the research by Nilsson and Darley (2006), in order to design an agent-based model, understanding of the existing complex system is required. Thus, the research was started by interviewing several key actors in the system, as well as observing the process of OrganicFe Co. Two of OrganicFe Co.'s employees were chosen for the interviews: one involved in the production processes of OrganicFe Co. and the other involved in the marketing and sales of their products. Another interview was also conducted with an expert knowledgeable about crops farming and the effect of OrganicFe Co.'s products on the crops.

After enough information was gathered from the interviews, the design of the agent-based model for the current system was developed. Generally, an agent-based model consists of agents and scenario. For each agent, their properties and their behavior to various triggers should be defined. The differences of properties distinguish one agent from another, as well as also possibly impacting their behavior towards the various

triggers within the system, both coming from the environment and the other agents. The scenario of the agent-based model contains the necessary information regarding the system that is not contained within the agents, including the workflow within which the agents would act. The interaction among agents with different behaviors would then result in a behavior of the system that is not initially defined, known as the emergent behavior of the system. In this research, the framework is illustrated in Figure 1. The interaction of farmers' characteristics, along with OrganicFe Co.'s marketing strategy and fertilizer quality (in suitability with farmers' crops), would then result in the emergent properties of Organic Co.'s fertilizer sales and farmers' on-grade harvest result.

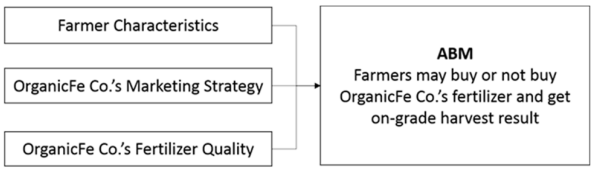

Figure 1. Research ABM Framework

IV.RESULTS AND DISCUSSION

From the interviews, there are several issues in the activities of OrganicFe Co., especially related to their interaction with other actors within the system. The behavior of several farmers (opportunistic, high pride) prevents them from buying the fertilizer continuously: some of the farmers only want to obtain free fertilizer samples and will not buy it, other farmers with high pride will not buy fertilizers if they see their neighbor already using it first, out of fear that they will be seen as followers, while others had bad experiences with other types of organic fertilizers. This all caused their distrust of the OrganicFe Co. products. There is also the fact that, according to the expert in crops farming, there are several other locally produced organic fertilizers with lower price compared to OrganicFe Co.'s fertilizer. According to this expert too, the company often mistakenly chooses a quality for crops to be focused on. For example, in bok choy vegetable, OrganicFe Co. claimed their product as being able to provide the best quality by the measure of the width of the leaves. However, according to the expert, bok choy's marketable quality is not the width of their leaves, but their sweetness and crunchiness. Then, there is also the inadequate standard of operation procedure from OrganicFe Co. to use their products': there is actually a requirement of soil pH for OrganicFe Co.'s fertilizer to work efficiently. However, there is no evaluation of soil pH level in OrganicFe Co.'s standard of procedure for fertilizer usage.

A. Agents Definition

The issues gathered from the interviews are then analyzed to become the agent-based model design for the system. Firstly, the agents for the model are defined. From the result of the interviews, there are two possible agents in the system: OrganicFe Co. and farmers. As OrganicFe Co. is the main actor of the case study, obviously the company would be one of the agents in the agent-based model. Then, there are farmers as the main customers of OrganicFe Co. They exhibit various behaviors and characteristics regarding their consumption of OrganicFe Co.'s products. While there are other actors in the system, they do not exhibit enough characteristics and behaviors to be made as independent agents. Thus, the inputs from other actors would be defined only as variables, which could be contained within the agents' properties and definition of environments. The next step following the definition of agents for the model is defining the properties for each agent.

The properties of OrganicFe Co. are presented in Table 1. For the existing system, it is determined that several properties are important and might cause different behaviors in the interaction. The first is the type of suitable crop for their fertilizer, as resulted from the research process. Then, the variable of crop quality knowledge, represented in true/false value. Afterwards, there is the strategy for the promotion and socialization. The three types of promotion and socialization strategy are related to the characteristics of farmers. There are also several properties related to the processes of OrganicFe Co. in producing their fertilizer. The number of organic fertilizer sales will become the observable outcome of this model.

TABLE 1. PROPERTIES OF ORGANICFE CO. AGENT

Agent	Property	Value
OrganicFe Co.	Suitable crop for produced fertilizer	The type of crops that could have their quality improved by the fertilizer
	Knowledge of crop quality	True/false
	Quality of fertilizer	From 0 to 1, with 0 being not suitable at all for the crop and 1 being very suitable
	Promotion and socialization strategy	Demonstration, influence of charismatic leader, contract
	Cost of organic wastes purchase	Rp 500 for each kg wastes
	Amount of organic wastes purchased	4 tons for each day
	Production time	4 to 5 days
	Amount of produced organic fertilizer	Claimed 20 tons for each day
	Organic fertilizer sales	Amount of sold organic fertilizer

Another agent type defined in the system is the farmer agent, and their properties are defined in Table 2. Firstly, there is the property of crop type. Farmers will purchase OrganicFe Co.'s fertilizer if their crop type matches OrganicFe Co.'s suitable crop property.

There are also the three properties related to the farmers' characteristics: high pride, opportunistic, and trust. The state of these properties will determine OrganicFe Co.'s promotion and socialization strategy. There is also the amount of fertilizer needed by the farmers along with their overall cost in fertilizer purchase. Finally, there is the amount of on-grade harvest result which could be sold to the market.

TABLE 2. PROPERTIES OF FARMER AGENT

Agent	Property	Description
Farmers	Crop type	The type of crops planted by the farmers
	Trust towards OrganicFe Co.	Yes/No
	High pride	Yes/No
	Opportunistic	Yes/No
	Fertilizer need	Depending on the farm area owned by the farmer
	Cost of fertilizer purchase	The fertilizer need times the cost of fertilizer (Rp 70,000 for each liter)
	On-grade harvest result	Amount of harvest result that could be sold to market

B. Scenario Definition

After the agents have been defined, the next step to be taken is defining the basic scenario in which the model would run. The basic scenario in this case would consist of the workflow of the agents in the model. It is illustrated in Figure 2. The main process of OrganicFe Co. is highlighted with solid lines, while the suggested additional process is highlighted with dotted lines. First, the model simulates the research process of OrganicFe Co. The research process starts with OrganicFe Co. purchasing the wastes from the providers. In the model, this will be represented by the waste purchasing cost property from OrganicFe Co., which is the result of amount of wastes purchased times the price for one kilogram of wastes, Rp 500. Afterwards, OrganicFe Co. would select the composition of wastes to be researched and produce the fertilizer. The resulting fertilizer is then tested for a type (or several types) of crops. If the fertilizer is not suitable for the crops planted by farmers, the research process is then repeated again. However, if the fertilizer is suitable for certain types of crops, then the fertilizer is marketable and OrganicFe Co. will keep producing the fertilizer, purchasing waste resources before conducting the production processes. Afterwards, the simulation will enter the promotion and socialization phase for the fertilizer.

The promotion and socialization phase is mostly conducted in the farmers' location. Basically, OrganicFe Co. will immediately promote and socialize their fertilizer for the farmers. However, from the theory considering that characteristics of customers are related to marketing strategy, it is suggested for OrganicFe Co. to firstly observe the condition of farmers by interacting with them. This is conducted to gather several types of information: the type of crops being planted by the farmers and the farmers' value for trust, pride, and opportunistic properties. Based on the majority of farmers, OrganicFe Co. should then make the decision whether to promote and socialize the fertilizer to these farmers, and what kind of promotion and socialization method, or marketing strategy, would be suitable for these farmers based on their characteristics. It is assumed that OrganicFe Co. would be able to successfully determine the right promotion and socialization method, ending with a fertilizer samples offer for the farmers and farmers trying the samples in their farming activities. The experience of farmers when they try the samples would affect the next step, also becoming the feedback for OrganicFe Co., the form of information regarding farmers' amount of on-grade harvest result.

The final phase of the model is the farmers' action after the trial. Suppose that the farmer had good experiences with the fertilizer, the farmer agent would then make a decision based on their property of being opportunistic or not. If the farmers are opportunistic, even though they have positive experiences with the fertilizer, they still would not buy the fertilizer. However, if the farmers are not opportunistic, they would buy the fertilizer and use it in the farming activities. These behaviors will result in sales of OrganicFe Co.'s fertilizer, along with farmers' on-grade harvest result. The result would be given to OrganicFe Co. as feedback, and would determine the farmers' experience with the fertilizer, thus repeatedly conducting the whole purchase and after purchase processes. It is also suggested for OrganicFe Co. to research concerning their fertilizer based on the farmers' feedback. This is to ensure that OrganicFe Co. gains better understanding about the farming practices, especially through the words of farmers who experience their product directly. The result of this research could possibly be used in their production processes, or to better the practices in utilizing their fertilizer, such as improving their standard operating procedure.

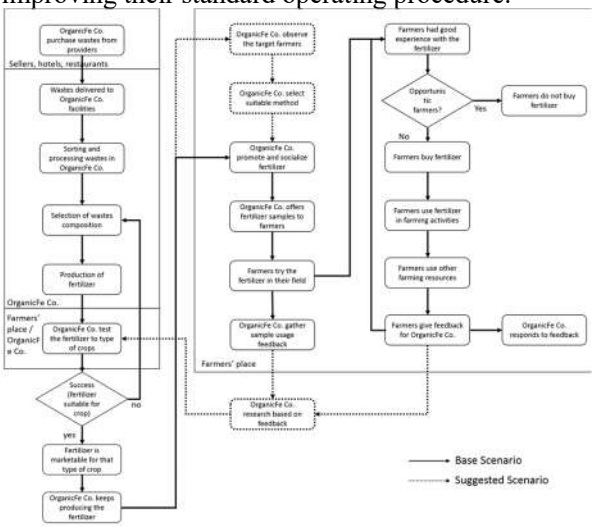

Figure 2. Scenario of agent-based model for OrganicFe Co.

V. CONCLUSION

The implementation of circular economy concepts might become an answer for the issue of economic value loss when by-products are treated as wastes in the agri-food industry. However, the implementation is not without obstacles. From the case of OrganicFe Co., it is found that there are obstacles arising from the interaction with various actors in the system, especially the farmers. The current situation is then analyzed from the perspective of agent-based model method, and a design consisting of agents and a scenario definition for the problem were made, with the emergent properties of this design being the sales of OrganicFe Co.'s fertilizer. The design, however, is still in early phase. It is focused on the problems of interaction between OrganicFe Co. and the farmers: incompatibility between farmers' characteristics and OrganicFe Co.'s marketing strategy, and also the lack of farming knowledge from OrganicFe Co.'s side. To handle the problems, it is suggested for OrganicFe Co. to observe the farmers before deciding their marketing strategy, also to expand their farming knowledge by utilizing feedback from the farmers.

From this model design, we can identify how the interaction progresses between OrganicFe Co. and the farmers. The possible points of interaction which possibly caused the problems were also identified, along with the possible actions to handle these points. Analyzing the case from an agent-based model framework allows us to gain deeper understanding of the actors, precisely how the differences between the perspectives of each actor could lead to misunderstanding and the failure to achieve collaboration between these actors. As in this case, OrganicFe Co.'s failure to understand the crops quality desired by the farmers led them to have bad perspectives on the fertilizer. Similarly, the farmers' various perspectives on the fertilizer, along with their characteristics, lead them to react differently to the marketing schemes, affecting their decision whether to purchase the fertilizer or not. As both actors only focus on their own interests and have no regard to the other actor, it leads to the failure of collaboration in this system.

There are several possible developments for the current agent-based model design. First, there might be the inclusion of other actors of the system as agents, especially if they exhibit certain characteristics and behavior in interaction with the OrganicFe Co. and farmer agents. Then, there is also the possibility to add other processes in the scenario workflow of the system, along with the inclusion of other actors. The processes might cover the whole agri-food supply chain in relation to the crops farming, so it can also visualize the system's circularity as the product flow for the whole supply chain is modeled. It is also possible to adjust the model for other cases related to the agri-food supply chain, especially those supporting the implementation of circular economy.

In regard to the problem of interaction between farmers and OrganicFe Co., there might be future researches in finding ways to enable collaboration between them. By utilizing the agent-based framework, we gain insights on how the current condition is and several possible additional processes for better collaboration. These processes should be delved into more, especially in terms of integrating them within a contract for better establishment of collaboration in the future. In relation to the contracts, the kind of incentives required by all actors for them to gain benefits from the participation could also be identified.

REFERENCES

[1] Paloviita, A. 2017. Food Security Is None Of Your Business?: Food Supply Chain Management In Support Of A Sustainable Food System. *Operations and Supply Chain Management*, *10*.

[2] Van der Vorst, J., Beulens, A., & van Beek, P. 2005. 10. Innovations in logistics and ICT in food supply chain networks. *Innovation in agri-food systems: Product quality and consumer acceptance*, 245.

[3] Pearce, D.W. & Turner, R. K. 1989. *Economics of Natural Resources and the Environment.* Johns Hopkins University Press.

[4] EM Foundation. 2012. Accelerating the scale-up across global supply chains. Available online at https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf (accessed on 20 February 2019)

[5] Badan Pusat Statistik. 2017. Statistik Lingkungan Hidup Indonesia 2017. Available online at https://www.bps.go.id/publication/2017/12/21/4acfbaac0328ddfcf8250475/statistik-lingkungan-hidup-indonesia-2017.html (accessed on 20 February 2019)

[6] Wilensky, U., & Rand, W. 2015. *An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo*. MIT Press.

[7] North, M., Macal, C., & Campbell, P. 2005. Oh behave! Agent-based behavioral representations in problem solving environments. *Future Generation Computer Systems*, *21*, no. 7, 1192-1198.

[8] Daloğlu, I., Nassauer, J., Riolo, R., & Scavia, D. 2014. An integrated social and ecological modeling framework—Impacts of agricultural conservation practices on water quality. *Ecology and Society*, *19,* No.3.

[9] Nilsson, F., & Darley, V. 2006. On complex adaptive systems and agent-based modelling for improving decision-making in manufacturing and logistics settings: Experiences from a packaging

company. *International Journal of Operations & Production Management*, *26*, no. 12, 1351-1373.
[10] Rahbar, E., & Abdul Wahid, N. 2011. Investigation of green marketing tools' effect on consumers' purchase behavior. *Business strategy series*, *12*, no. 2, 73-83.
[11] Jiuan Tan, S. 1999. Strategies for reducing consumers' risk aversion in Internet shopping. *Journal of consumer marketing*, *16,* no. 2,163-180.
[12] Verhoef, P.C., Reinartz, W.J. and Krafft, M. 2010. Customer engagement as a new perspective in customer management. *Journal of service research*, *13,* no. 3, 247-252.