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THE DEVELOPMENT OF FOOD SECURITY BEHAVIOR MODEL THROUGH ENVIRONMENTAL-BASED LEARNING: A SYSTEM DYNAMICS APPROACH

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ABSTRACT

Food security behavior is essential to be developed through continuous development of knowledge, awareness, attitudes, values, skills, and responsibility. Utilization of system dynamics methodology in educational research in the field of food security is still limited. Thus, this research aimed to develop a model of food security behavior through environmental-based learning by utilizing a system dynamics methodology. This approach starts with defining problems dynamically, developing concepts in circular causality, identifying stocks, flows, simulating, and validating the model. Through quantification of variables involved in the development of food security behavior model, the results showed that during 6 years of simulation, environmental-based learning could improve food security behavior sustainably (from 10.60 at the beginning to 74.19 at the end of simulation year) having the growth forming an exponential curve. The increase of food security behavior occurred gradually through increasing food security attitudes (from 2.09 to 7.45), food security awareness (from 0.55 to 2.34), food security values (from 0.23 to 0.85), food security knowledge (from 1.53 to 6.17), food security skills (from 0.61 to 1.83), and food security responsibility (from 0.88 to 1.67).

Keywords: food security behavior, environmental-based learning, system dynamics methodology

INTRODUCTION

Today, food security has become the primary concern of every country in the world because of its essential role in supporting sustainable development. There are approximately 1 billion people (16% of the total world population) today who suffer from chronic hunger when there is more than enough food available for all humanity (Mc Carthy et al., 2018). According to Food and Agriculture Organization (FAO), the prevalence of malnutrition in the world is 10.8% and 11.0%, or 794 and 815 million according to 2015 and 2016 data (Prosekov & Ivanova, 2018). Up to now, food security in India remains to be a major problem because of India's position in the ranking of 100 of 119 countries in the world according to Global Hunger Index (Chakraborty & Sarmah, 2019). According to FAO, the proportion

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of population lacking food in Sub Sahara Africa has decreased from 28.1% (178 million) in 2000 to 20.6% (171 million) in 2010; however, there was an increase of 200 million people (20.8%) in 2015 to 224 million (22.7%) in 2016 (Degarege & Lovelock, 2019). In Indonesia, the biggest challenge for food security is how to guarantee access and availability of sufficient and nutritious food for people who now have exceeded 265 million. Cases of child malnutrition, for example, are difficult challenges to solve. Stunting has occurred at 37 percent of Indonesian children under the age of 5 in 2013 (compared with the same case, it only happened at 12 percent of children throughout East Asia and the Pacific) (Neilson & Wright, 2017).

Various global environmental problems are thought to be the cause of these conditions. Climate change, loss of agricultural land, and minimized access to water resources have become a threat to sustainable food security (Ligmann-Zielinska & Rivers, 2018). In Morocco, climate change and increasing demand for industrial and household needs have significantly reduced the availability of water resources (Amahmid et al., 2018). In China, food security has become a genuine national crisis throughout the development process in the country. The Chinese government has even made a big step to guarantee the safety of the food supply chain by regulating it in food safety law in 2009 (Bai & Gong, 2017). The Government of India enacted the National Food Security Act in 2013 to ensure that communities obtain adequate access to food both in quantity and quality (Chakraborty & Sarmah, 2019). In Indonesia, through Law Number 18 of 2012, the Government has issued a regulation on food which aims to ensure food availability and adequate access for all people.

There is no single solution to solve food security problems in the future (Nooghabi et al., 2018). A system approach is needed, which is a combination of technology and policy reform integrated with state-of-the-art technologies, techniques, and best practices (Mc Carthy et al., 2018). The role and function of an institution in facing future uncertainty in the field of natural resource management, climate change adaptation, and food security are considered very important (Gebreyes, 2018). Integration between sectors and stakeholders at various levels of government is needed with the primary goal of minimizing possible trade-offs between food production and conservation; also, maximizing synergy through proper management (Jiren et al., 2018). Efforts to resolve the food security problem are also carried out across disciplines. Through cross-disciplinary considerations, educated workers and development of curricular framework are needed not only in the fields of traditional food safety and security, but also in the food production, sustainable practices, and ecosystem health (Angelos et al., 2017). Education on nutrition and resource management is needed to reduce food insecurity (Kaiser et al., 2015). Achieving sustainable food security must also be combined with societal changes through knowledge, attitudes, and behavior (Amahmid et al., 2018).

Food security behavior is an inseparable part of environmental behavior. The development of environmental behavior is important because behavior change requires knowledge, awareness, attitudes, values, skills, and responsibility that need to be instilled early (Zareie & Navimipour, 2016). Environmental knowledge has the potential to support positive environmental attitudes and behavior (Braun et al., 2018). Environmental behavior reflects environmental knowledge. Environmental behavior is a function of environmental attitudes that is expanded by environmental responsibility, knowledge, and values (Kaiser et al., 1999).

Nevertheless, there are slightly different research results in terms of energy consumption. For example, Paço & Lavrador (2017) shows the low relationship between environmental knowledge and attitude as well as between environmental knowledge and behavior. However, the connection between environmental attitude and behavior is weak. The weakness of relationship was also demonstrated by Romero et al. (2018) who said that even though someone has a desire to adopt environmental behavior well, the absence of norms, laws, and other social institutions often causes a broader gap between environmental attitudes and behavior.

Learning resources are everything that can be used to help students achieve their learning goals. Learning resources provide contextual information and perspectives on how to interpret data, make relations between concepts, and bridge the gap between theoretical understanding and practical knowledge (Jeong & Hmelo-Silver, 2010). Textbooks as a conventional learning resource are only able to help achieve cognitive abilities at low and middle levels such as remembering, understanding, applying, and analyzing; while a higher level of cognitive abilities such as evaluating and creating are difficult to be facilitated by these learning resources (Lau et al., 2018). Based on these reasons, environmental-based learning resources are important to achieve high-level cognitive abilities as well as authentic and up-to-date information that is not necessarily available in the textbook.

There are two kinds of learning resources, namely endogenous learning resources (learning capital) and exogenous learning resources (educational capital) (Ziegler et al., 2017; Vladut et al., 2015). Learning capital encompasses all potential and learning abilities in each, while educational capital includes all resources in the environment that can be used to support the learning process. Environmental-based learning is oriented to the use of educational capital to support the learning process. This learning utilizes cultural, educational capital (for example value system, model, and mindset that develops in society) to achieve learning goals. It also uses social, educational capital (covering all persons or relevant social institutions) to support the learning process. Also, it also adopts biophysical educational capital (covering all potential natural resources, both biological and physical) to achieve learning objectives. In the context of environmental-based learning, ecological wisdom is a concept that combines cultural, social, and biophysical educational capital and is useful for the development of sustainable management in the 21st century (Patten, 2016). In the frame of Indonesia, the local wisdom of Baduy community in efforts to preserve the environment is an example of the context of science in environmental management issues (El Islami et al., 2018).

The development of food security behavior involves broad dimensions and complex variables. System approach in the development of food security behavior is vital because of problem complexity that needs to be solved comprehensively. In this context, system dynamics is appropriate to use. System dynamics is an action research approach to learn complex systems (Richardson, 2011; Shen et al., 2009). System dynamics was initially used in the business and industrial fields but currently has expanded to almost all fields, including environment and education (Nuhoglu & Nuhoglu, 2007). The use of system dynamics in various scientific fields has been carried out. For example, Mutingi et al. (2017) in energy sector, Barisa & Rosa (2018) on mitigating CO2 emissions, Pizzitutti et al. (2017) on tourism management, Walrave & Raven (2016) on technological innovation systems, Elias (2012) on the management of environmental conflicts, and Purnomo & Mendoza (2011) on forestry management. In limited terms, the use of system dynamics in educational research has also been carried out. For example, Strauss & Borenstein (2015) utilized system dynamics in planning long-term undergraduate education. Faham et al. (2016) employed system dynamics to develop education for sustainable development, which emphasizes on student competency. Allena-Ozolina & Bazbauers (2017) applied system dynamics in research, innovation, and education systems to efficiently utilize bio-resources. Upadhayay & Vrat (2016) adopted system dynamics to analyze the impact of industry-academic interactions on the quality of technical education. Nevertheless, the use of system dynamics methodology in educational research in the field of food security behavior has never been done. Based on these conditions, this research was designed to utilize system dynamics in the development of food security behavior through environmental-based learning.

METHODS

This research used system dynamics methodology. The novelty lies in the method adopted. By utilizing this method, the complexity of the relationships between variables, which are characterized by nonlinear feedback loops, can be modeled effectively. The software used was Powersim Studio 7. System dynamics is a methodology for studying and managing complex systems, involving multiple relationships and interdependencies, through developing representative models that reflect actual conditions (Elias, 2012).

Moreover, it is an action research approach to study a complex system and to understand complex organizational behavior (Richardson, 2011). System dynamics approach is a simulation technique created by J.W. Forrester in 1950 to help managers improve industrial processes that have dynamic behavior (Saavedra et al., 2018). Characteristic of system dynamics is the existence of feedback loops (Drmola et al., 2015) that have an impact on complex system behavior and must be considered when designing policies (Duryan et al., 2012). Loop is a technical term that gives an image of a serpent that is swallowing its tail, a symbol of continuity, or interconnection (Mella, 2008). System dynamics approach focuses on 4 basic ideas: (1) designed from stocks and flows; (2) stocks and flows has a feedback loop; (3) feedback loops work to form a nonlinear relationship; and (4) simulation to model complex system dynamics (Nuhoglu & Nuhoglu, 2007). Feedback loops are represented in causal loop diagrams. In system dynamics, the design of the causal loop diagram is an iterative and qualitative process (Duryan et al., 2014). Causal loop diagram illustrates the relationship between two reciprocal variables. There are 2 types of loops, reinforcing loop (R) and balancing loops (B) (Kontogiannis, 2012). Figures 1a and 1b provide illustrations of both. Figure 1a (R) illustrates a mutually reinforcing relationship between variables A and B. Increasing A will increase B (+). Conversely, increasing B will increase A (+). Figure 1b (B) illustrates the mutually balancing relationship between variables C and D. Increasing C will increase D (+). Conversely, increasing D will decrease C (-).

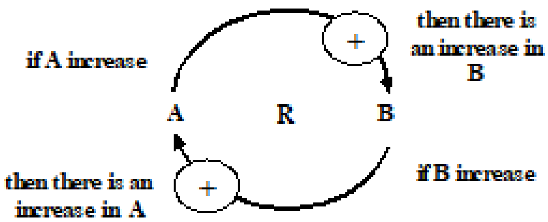

Figure 1a. Reinforcing Loop (R) which Illustrates the Mutually Reinforcing Relationship between Variables A and B

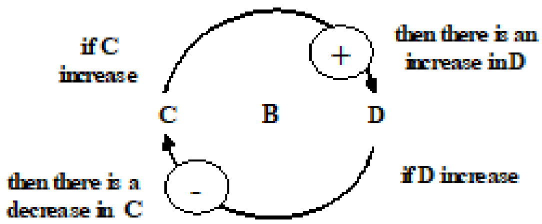

Figure 1b. Balancing Loop (B) which Illustrates the Mutually Balancing Relationship between Variables A and B

Stocks and flows are constituent components of flow diagrams that are linked using directed arrows to show interrelationships between system elements (Purnomo & Mendoza, 2011). Rectangles symbolize a stock, and valves express flow. A stock represents an accumulation of information in the system. A flow represents a rate of change of information that occurs in stocks. Besides, there are also auxiliaries (symbolized by circles) which are intermediate variables and function as the representation of various calculations that connect variables. Constant represents a fixed quantity that affects a variable. Arrow sign represents the built causality of the relationship between variables in the structure. Simple flow diagrams which illustrate a relationship between variables involved in the construction of the model is presented in Figure 2.

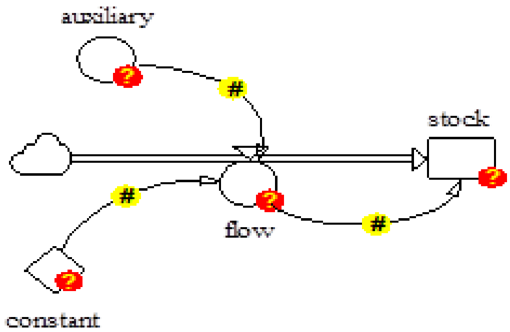

Figure 2. Simple Flow Diagram Illustrating the Relationships between Variables in System Dynamics

The modeling steps use system dynamics as follows (Abdolvandi et al., 2013): (1) identifying and defining the problem; (2) describing and conceptualizing the system; (3) making a dynamic assumption; (4) making a simulation model; (5) developing a model; (6) verifying the model; and (7) analyzing and improving the model. These steps are diagrammatically presented in Figure 3.

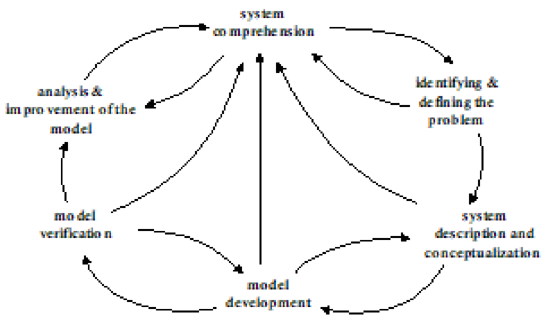

Figure 3. Steps of System Dynamics Modeling (Abdolvandi et al., 2013)

RESULTS AND DISCUSSION

Zareie & Navimipour (2016) has succeeded in establishing a conceptual model that addresses the relationship between environmental behavior with attitudes, awareness, values, knowledge, skills, and responsibility. However, it is known that there is no single framework that can predict and accurately describe the relationship between environmental attitudes, knowledge, and behavior (Braun et al., 2018). Assuming that food security behavior is an integral part of environmental behavior, then a conceptual model of the relationship between food security behavior and food security attitudes, food security awareness, food security values, food security knowledge, food security skills, and food security responsibility was made (Figure 4).

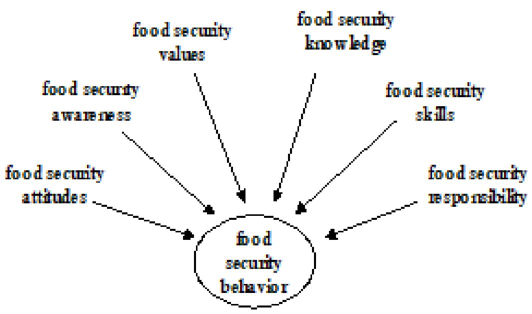

Figure 4. Conceptual Model on Food Security Behavior

Based on Figure 4, it is known that there is a non-reciprocal relationship between food security behavior and the six supporting variables. Increasing food security attitudes will raise food security behavior. Improving food security awareness will escalate food security behavior. Increasing food security values will elevate food security behavior. Enhancing food security knowledge will increase food security behavior. Increasing food security skills will ameliorate food security behavior. Enhancing food security responsibility will increase food security behavior. Figure 4 is a conceptual model that is built on the understanding of relationships between linear variables.

Based on this conceptual model, then a new model is built based on the understanding that relationships between variables can also be reciprocal; in such a way that it can produce exponential patterns of growth/decay. In this case, the use of a reinforcing loop (R) in the built model causes only an exponential growth pattern.

To build a dynamic model structure, information obtained from Figure 4 was then developed through the logic of causal relationships so that it produced a causal loop diagram (Figure 5). As support for completing the model, the variable of environmental-based learning is also integrated into the structure.

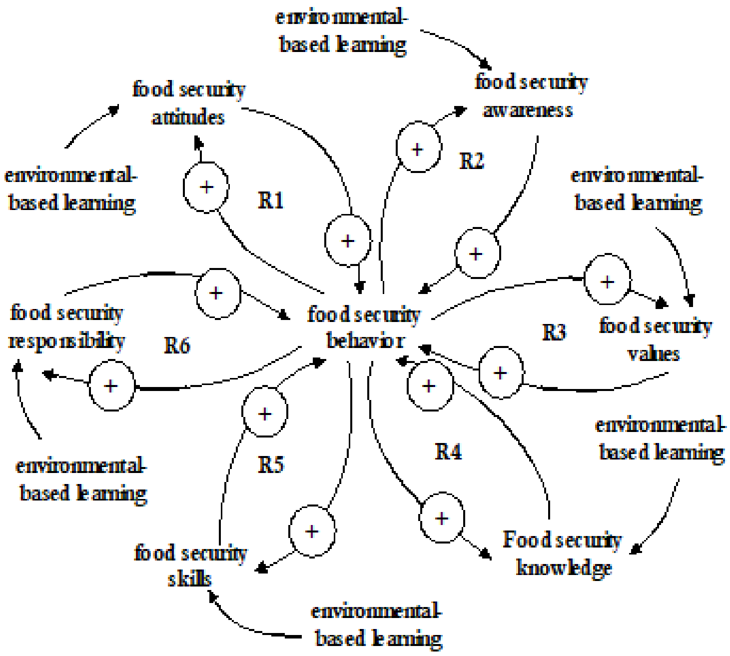

Figure 5. Causal Loop Diagram on Food Security Behavior

Figure 5 indicates that there is only one type of relationship between variables, reinforcing loop (R). On R1, there are reciprocal relationships that strengthen each other between food security attitude and food security behavior. Increasing food security attitude will raise food security behavior. Conversely, increasing food security behavior will increase food security attitude. Mutually reinforcing relationships also occur between food security awareness and food security behavior (R2). Improving food security awareness will increase food security behavior.

Conversely, increasing food security behavior will increase food security awareness. Mutually reinforcing relationships also occur between food security values and food security behavior (R3). Enhancing food security values will increase food security behavior. Conversely, increasing food security behavior will increase food security values. Mutually reinforcing relationships also occur between food security knowledge and food security behavior (R4). Improving food security knowledge will increase food security behavior.

Oppositely, increasing food security behavior will increase food security knowledge. Mutually reinforcing relationships also occur between food security skills and food security behavior (R5). Increasing food security skills will enhance food security behavior. Conversely, increasing food security behavior will escalate food security skills. Mutually reinforcing relationships also occur between food security responsibility and food security behavior (R6). Improving food security responsibility will elevate food security behavior. Conversely, increasing food security behavior will increase food security responsibility. On the causal loop diagram (Figure 5), environmental-based learning is a variable that directly affects all variables involved.

Figure 6 shows a flow diagram called food security behavior model (FSBM). It is the primary model developed from the causal loop diagram in Figure 5. FSBM has 1 stock (food security behavior) with an initial score of 10.6. This stock is influenced by the rate of change of 6 auxiliaries as follows:

1. Food security attitudes is a graph function with powersim equation GRAPHCURVE (‘environmental-based learning’,0,0.1, {1.14, 1.174,1.22,1.33,1.406,1.51,1.574,1.645,1.794,1.89//Min:1.5;Max:2//})
2. Food security awareness is a graph function with powersim equation GRAPHCURVE (‘environmental-based learning’, 0,0.1, {0.1, 0.19,0.22,0.23,0.29,0.35,0.426,0.445,0.46,0.484//Min:0;Max:1//})
3. Food security values is a graph function with powersim equation GRAPHCURVE (‘environmental-based learning’, 0,1,{0.12,0.22,0.28,0.41,0.5,0.61,0.69,0.77, 0.83, 0.89 //Min:0; Max: 1//})
4. Food security knowledge is a graph func- tion with powersim equation GRAPH- CURVE (‘environmental-based learn- ing’,0,0.1,{1.11,1.13, 1.13, 1.116,1.142,1.177,1.23,1.28,1.3,1.355//Min:1;Max:1.5//})
5. Food security skills is a graph function with powersim equation GRAPHCURVE (‘envi- ronmental-based learning’,0,0.1,{0.12,0.12, 0.14,0.174,0.22,0.3, 0.355,0.41,0.52,0.56//Min:0; Max:1//})
6. Food security responsibility is a graph func- tion with powersim equation GRAPH- CURVE (‘environmental-based learn- ing’,0,0.1,{0.09,0.25, 0.34, 0.43,0.52,0.69,0.716,0.75,0.82,0.845//Min:0;Max:1//}).

Environmental-based learning is an auxiliary with powersim equation: factor of learning*food security behavior. There are 7 constants in FSBM: factor of learning 0.11<<1/point>>, factor of attitudes 0.11<<1/yr>>, factor of awareness 0.001<<1/yr>>, factor of values 0.007<<1/ yr>>, factor of knowledge 0.0013<<1/yr>>, factor of skills 0.0001<<1/yr>>, and factor of responsibility 0.002<<1/yr>>.

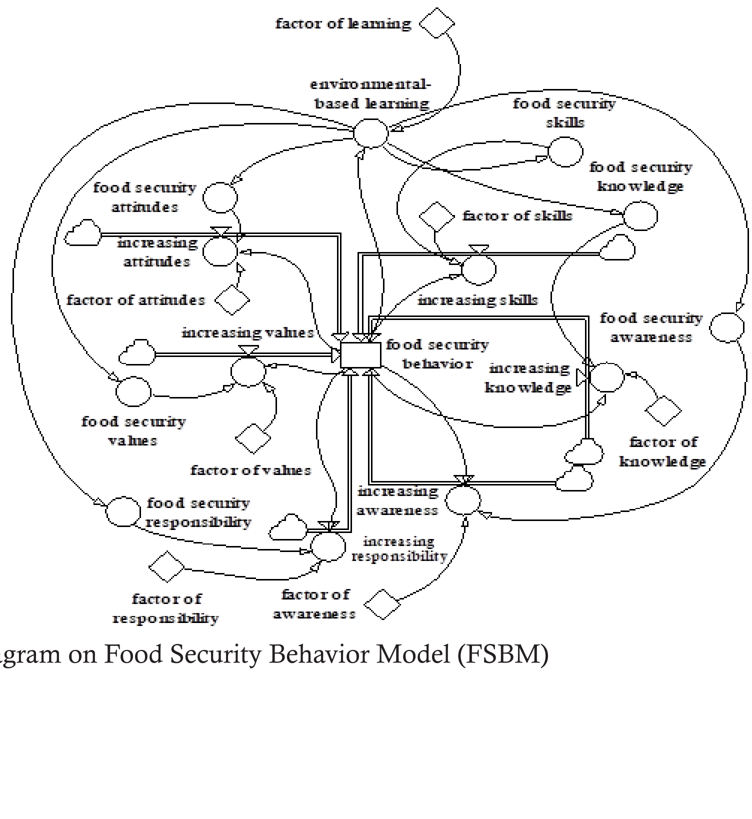

Figure 6. Flow Diagram on Food Security Behavior Model (FSBM)

Assumptions underlying the development of FSBM are as follows: (1) Food security behavior is a variable that is not affected by variables other than food security attitudes, food security awareness, food security values, food security knowledge, food security skills, and food security responsibility; (2) Food security behavior is a leading variable measured quantitatively in the range 0-100; (3) Food security attitudes, food security awareness, food security values, food security knowledge, food security skills, and food security responsibility are supporting variables measured quantitatively in the range 0-10; (4) simulation period starts in 2013 until 2018; and (5) measurement of these variables was carried out on the students of State Primary School Banjarsari 2, Serang, Banten based on information obtained from the class teacher. Some technical terms are explained as follows: food security attitudes is a perception that is built on values and beliefs which then raises verbal and actual commitment, motivation, and intention to actively participate in sustainable food security; food security awareness is the ability to feel or to be conscious of an object, event, emotion, thought or other sensory patterns related to food security problems; food security values are fundamental cultural factors that influence attitudes, norms, beliefs and behavior towards sustainable food security; food security knowledge is the ability to identify symbols, concepts, and behavioral patterns related to food security; food security skill is the ability to select appropriate strategy, also to create, evaluate, and implement an action plan related to food security; food security responsibility is responsibility towards food security improvement include persuasion, consumer action, management, political and legal action; food security behavior is a preventive action to protect the environment and addressing food security issues (Zsóka et al., 2013); (Zareie & Navimipour, 2016).

From the flow diagram, a simulation is then carried out to determine system behavior (Figure 7). The simulation was done using the Euler method (fixed step) at 1st order. The simulation shows that during 6 years running process (2013-2018), food security behavior increased significantly (from 10.60 at the beginning to 74.19 at the end of the simulation year) and formed an exponential curve. This phenomenon can be explained through 2 reasons:

It is generated by reinforcing loop assuming all variables can be controlled properly. In this case, the variables can be internal or external (Ziegler et al., 2017). Internal variables are endogenous and consist of organismic, actional, telic, and attentional learning capital; while external variables are exogenous and include economic, infrastructural, cultural, social, and didactic educational capital.

Simulations of six supporting variables show that their growth patterns follow the main variables (Figure 8). According to Figure 8, food security attitudes grow exponentially from 2.09 to 7.45, food security awareness grows exponentially from 0.55 to 2.34, food security values grow exponentially from 0.23 to 0.85, food security knowledge grows exponentially from 1.53 to 6.17, food security skills grow exponentially from 0.61 to 1.83, and food security responsibility grows exponentially from 0.88 to 1.67.

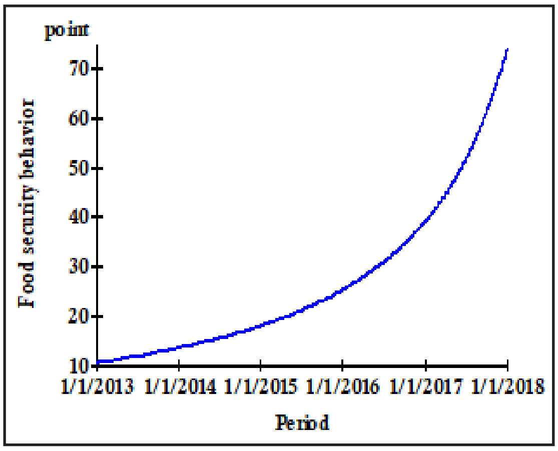

Figure 7. Simulation of the Growth of Food Security Behavior

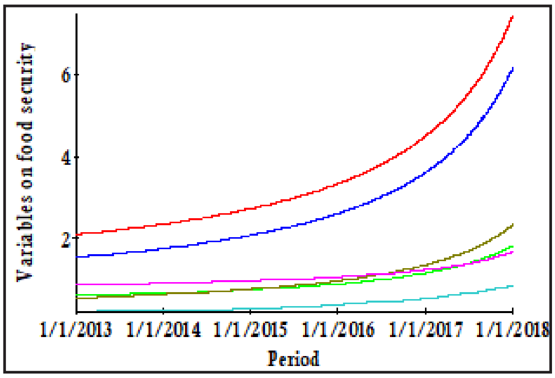

Figure 8. Simulation of the Growth of Supporting Variables Related to Food Security Behavior (— = Food Security Attitudes; — = Food Security Knowledge, — = Food Security Awareness; — = Food Security Skills; — = Food Security Responsibility; — = Food Security Values)

Based on the characteristics of the reinforcing loop (R), it can be understood that R contributes to this exponential growth pattern. This is consistent with Kim & Anderson (1998), who said that exponential growth usually indicates the presence of a reinforcing process. From the view of the linear relationship between variables, Zareie & Navimipour (2016) explained that environmental attitudes, awareness, values, knowledge, skills, and responsibility (6 supporting variables) directly influence the environmental behavior with R2 = 0.615. This means that the six supporting variables have an effect of 61.5% on the primary variable (environmental behavior), while the other 38.5% is influenced by other variables.

Figure 9 shows the relationship between environmental responsibility, knowledge, and values with intentions and ecological behavior.

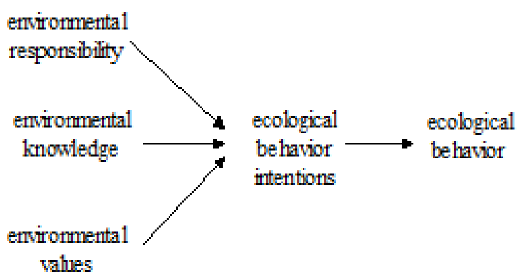

Figure 9. Ecological Behavior as a Function of Environmental Knowledge Extended by Responsibility and Values (Kaiser et al., 1999).

As illustrated in Figure 9, it is known that environmental knowledge, values, and responsibility predict ecological behavior intentions, which in turn predict environmental behavior. Environmental responsibility is a bridge that connects the gap between rational choice and norm-activation theory. The logical choice theory assumes that moral aspects have never been a driver of ecological behavior, so this theory believes that ecological behavior is only driven by logic; while norm-activation theory is the opposite, that besides being driven by logic, the moral aspect is always behind ecological behavior (Kaiser et al., 1999).

Figure 10 shows the relationship between beliefs, attitudes, intention, and behavior. In accordance with norm-activation theory, Ajzen & Fishbein (1980) elucidated that the main determinants of behavior are behavioral beliefs and normative beliefs. Intentions do not only influenced by attitude but also normative considerations. Attitudes do not determine behavior directly, but behavior intentions first then behavior.

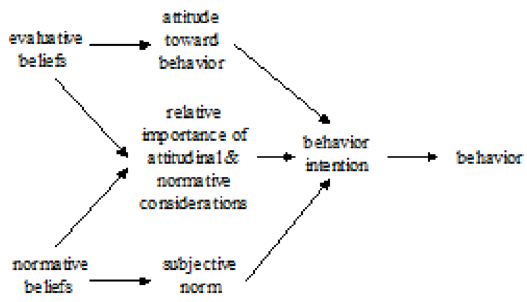

Figure 10. Theory of Reasoned Action (Ajzen & Fishbein, 1980)

Validity analysis is used to determine suitability between the built model with the real conditions. In this research, performance validation is used to determine the extent to which the model performance is compatible with system performance. The results of the validity analysis are shown in Figure 11. Because there is no score of food security knowledge in elementary school, the data used is the average score of general knowledge of students since grades I to VI obtained from a class teacher. Food security knowledge is an integral part of public knowledge. This 100 scale score is then converted to a scale of 10. This data is then compared to its suitability with food security knowledge originating from the built model.

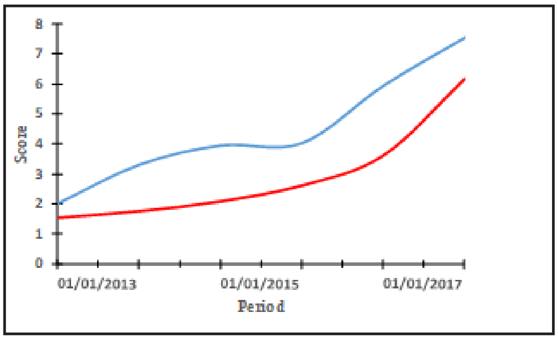

Figure 11. Comparison between General Knowledge and Food Security Knowledge (— = General Knowledge; — = Food Security Knowledge)

Figure 11 informs that growth pattern shown by food security knowledge has a tendency that is consistent with general knowledge. Data suitability is shown as follows: in the beginning, score of food security knowledge is 1.53 compared to score of general knowledge 2.01; in the middle, score of food security knowledge is 2.08 compared with score of general knowledge 3.94; in the end, score of food security knowledge is 6.17 compared with score of general knowledge 7.53. Based on these data, it is known that the behavior of the model with the behavior of the actual data on the variable of food security knowledge is identical (both form an archetype of exponential growth). Model validation was statistically analyzed by using the value of absolute means error (AME) and absolute variation error (AVE). The model is declared valid if AME value is ≤ 5% and AVE value is ≤ 30%. Analysis results show that AME value is 0.36; while AVE value is 1.42. Thus, based on the above criteria, it is known that the model is valid.

CONCLUSION

System dynamics methodology is used to study and manage complex systems, involving multiple relationships and interdependencies, and through the development of representative models that reflect actual conditions. As a dynamic model, food security behavior model was built with food security behavior as the primary variable and food security attitudes, food security awareness, food security values, food security knowledge, food security skills, and food security responsibility as supporting variables. The model simulation shows that during 6 years of the process, food security behavior grew exponentially from 10.60 to 74.19. The growth of six supporting variables supports the growth of food security behavior. Food security attitudes grow exponentially from 2.09 to 7.45, food security awareness from 0.55 to 2.34, food security values from 0.23 to 0.85, food security knowledge from 1.53 to 6.17, food security skills from 0.61 to 1.83, and food security responsibility from 0.88 to 1.67. Theoretically, food security behavior is determined by behavioral beliefs and normative beliefs. Both of them influence attitude and behavior intention before finally affecting food security behavior.

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