Food Security Model in Corn Commodity Concerning on Welfare of Corn Farmers and Chicken Farmers in East Java

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Abstract

Food is one of the basic human needs. Government has set strategic commodity targets, one of which is corn and chicken. Corn is an important agricultural commodity for humans and livestock. There is a challenge where the increase in corn production is going slow so far. As a result, the speed of increasing demand for corn cannot be pursued to increase production. This also has an impact on chicken farmers which have a mutualism symbiotic with corn farmers. The selling price of corn and the right price of fodder will produce the right price of chicken and chicken eggs. This condition will have an impact to the welfare of corn and chicken farmers. This study aims to project the adequacy of corn both for humans and fodder by concerning the welfare of corn farmers and chicken farmers with parameters of corn and fodder prices. An approach with a dynamic system simulation is carried out to achieve a balance between the welfare of corn farmers and chicken farmers to be able to maintain their future existence based on corn prices and fodder prices. This approach is used because of the ability of this model to solve complex system behaviour between variables.

Keywords
Food security, corn demand, fodder demand, corn proce, fodder price, dynamics system

1. Introduction

Food is one of the basic human needs which should be fulfilled at all the times, so that food acquisition can be said to be one of human rights (FAO 1996). Moreover, food is a basic component to realize quality human resources (Panikkai et al. 2017). Following this up, the certainty of the availability of consistent and regular food is very important for food security (Namany 2020). Food security is a multi-dimensional and dynamic concept that requires interconnected entities including producers, customers and policy makers to work together in a well-organized and fully functional service-oriented supply chain (FAO 1996). Thus, to achieve food security, the food sector strives to ensure the sustainability and efficiency of food production (Moragues 2017). Through sustained food production, food availability will become more certain.

However, the achievement of food availability has several obstacles, such as uncertainty and risks governing food production and supply, including natural disasters, unstable international trade policies and political conflicts (Namany 2020). To overcome these obstacles, policymakers make food insecurity the main concern at various scales which requires global action on how to deal with it (Kpienbaareh and Luginaah 2019). One of them is related to the productivity of the food system so that food production does not only offset population growth but also increases food security in many areas (Vermeulen et al. 2013). So that, as a country with the fourth highest population in the world, Indonesia is always trying to reduce food insecurity in many areas starting from the provincial, district and sub-district levels (Panikkai et al. 2017). Therefore, food security becomes an important concern for the government, not only in its fulfilment, but also for the right price so that it can be affordable for the community. Food production can be affected which leads to higher prices whenever commodities become more scarce (Wheeler and Von 2013). Furthermore, the availability of food should be supported by food providers, those who produce food to maintain their welfare, so that they can produce food in a sustainable manner.

In order to realize sustainable food security, the government sets strategic commodity targets, namely staple food which gets top priority in achieving food self-sufficiency (Development AR and Strategic Food Outlook 2015). The

strategic commodities are rice, corn, soybeans, sugar, and meat, especially chicken. As a strategic commodity, corn is not only an important agricultural commodity for humans, but also for livestock, where one of them is chicken. Fulfilments of national corn needs is largely met by the Province of East Java, amounting to 31.3% of total national production (National Statistics Center 2019).

When the livestock industry began to develop, especially poultry, the use of corn gradually shifted from human staple food to fodder (Tangendjaja et al. 2005). This is in line with the multifunction of corn utilization (Panikkai et al. 2017), namely corn is a commodity that has a multipurpose function, both for food, feed, fuel, and industrial raw materials. The proportion of corn utilization are for fodder is estimated to reach more than 58% (in which fodder is composed of 51.4% corn), while for food is around 30% and the rests are for other industrial needs and seeds). Therefore, the government's effort to supply enough corn from domestic production is very important in supporting the development of the fodder industry and, let alone the chicken industry in Indonesia (Sulaiman et al. 2018). Chicken livestock that produce chicken in Indonesia are one of the main commodities providing protein needs that are affordable for the community. In recent years, there has been an increase in consumption per capita of chicken and chicken eggs, shown in Table 1.

Table 1. Average consumption of chicken and chicken eggs per year.

Year	Chicken (kg)	Chicken eggs (kg)
2013	4.06	8.79
2014	4.47	8.89
2015	5.36	100.88
2016	5.77	103.12
2017	6.43	110.17

It appears that average consumption of chicken and chicken eggs continuously increase year by year shown in Figure 1. The increasing consumption is challenged by the rising of chicken and chicken eggs prices. The increase of chicken price occurs along with the increase of the main fodder ingredients price, namely corn (Sulaiman et al. 2018). This happens because of the challenges in fulfilling corn, one of which is the area of corn plantations that have not increased in the last 20 years. Other than that are fluctuating rainfall, East Java province prone to natural disasters and increasing population (East Java Food Security Agency 2015). Based on these conditions, food security becomes a problem that has a high complexity. If the corn fulfilment policy is not right, it will cause new problems, that is when imports are carried out together with the harvest period, this condition will lead to abundant supplies and impact the corn prices to have downward trend. The existence of uncertainty in this matter can lead to losses the uncertainty regarding this matter can lead to losses of income of corn farmers as well as the potential replacement of commodities planted by corn farmers. If this happens, the existence of corn farmers will decrease in the next few years, which can threaten the adequacy of corn, even more for chicken fodder. Furthermore, broiler and laying hens' breeders have mutualism symbiotic with corn farmers. The availability and the right selling price of corn will have an impact on the price of chicken and eggs, too, which in turn will have an impact on the welfare of corn farmers and chicken farmers.

To be able to solve these problems, to achieve the fulfilment of corn commodity at an appropriate price, an approach with dynamic system simulation is used. This approach is used because of the ability of this model to solve complex system behaviour between variables (Gilbert and Troitzsch 2005). One study of corn commodities in previous studies has been done, but only focused on corn availability (Panikkai et al. 2017). However, this research does not include the number of corn farmers as producers of corn, as well as the main consumers of corn, namely feed mills, and chicken farmers. As previously stated, corn is one of the strategic commodities in Indonesia as the main ingredient of animal feed for broilers and laying hens which is the main source of animal protein besides beef. Furthermore, although it is known as the main source of protein, up until this time there is little research related to chicken meat and chicken eggs price stability as the implication of challenges in corn security.

Reference (Vanany et al. 2019) had corn, chicken and chicken eggs as the object of research which aimed to produce a food security model for eggs and meat commodities in East Java. The results showed that there would be a reduction in land each year which would ultimately not be able to meet the needs of corn in East Java, hence importing would

be needed to fulfil the demand. References (Juned et al. 2020) also conducted research related to food security with the object of research is rice as the object. The research aimed to determine the projected adequacy of rice in East Java using system dynamic simulation approach. The results of the study showed that in the next 15 years the area of land and rice production will decrease, but the condition is still in a surplus condition, so that the surplus will be supplied to other regions. Furthermore, reference (Guma 2018) used dynamic system simulation approach in households to model food availability strategies independently to achieve household food security given the occurrence of food insecurity in Uganda with a percentage of 35-59%. The results showed that in the three-year period there was 180% increase of income from current values. In addition to the puzzle references (Tsolakis and Srai 2017) also conducted a similar study on cereal commodities, which aimed to identify the role of small farmers in food security and challenges related to its sustainability in developed countries, the results showed that implementing policy interventions to develop new small farms might extend food security status in the UK for almost three years and increased the average annual gross domestic product at 2.33%.

Based on the previous studies, to mitigate challenges that threaten the food system stability, food sector decision making must be improved and be strong to accommodate any changes causing food shortages. The dynamic model can predict the food system's behaviour to avoid potential future effects of deficits and to ensure the performance of a sustainable food system (Namany et al. 2020). Reference (Kpienbaareh and Luginaah 2019) stated that policy interventions were aimed to deal with situations at various scales. In consequence, reference (Herrera and Kopainsky 2019), also took system dynamics (SD) approach to explore complex mechanisms affecting resiliency in a complex systems. In addition systems dynamics approaches have been widely used in the past to understand the interrelationships in agricultural systems and complex behaviour patterns (Rigolot et al. 2017; Bastan et al. 2017)

Thus, a dynamic simulation approach will be used to meet the corn availability and to pay attention to the welfare of corn farmers and chicken farmers based on corn price and the right price of fodder. As for the dynamic simulation approach, there will be several stages of modelling (Gilbert and Troitzsch 2005), including problem articulation (boundary selection), formulation of dynamic hypothesis, formulation of a simulation model, testing, and policy design & evaluation.

2. Methodology

The purpose of this study was to determine the adequacy of corn and the appropriate price between corn and chicken fodder in East Java. Based on these objectives, the main object in this study is corn, and chicken farmers as the main consumers of corn as fodder. The research was conducted in several stages, including initial identification, data collection, model development, model verification and validation, and analysis and interpretation of research results.

2.1. Initial Identification Phase

At this step, a literature review of food in East Java at this time was conducted, specifically the fulfilment of corn demand. Based on the initial result, a further literature review was collecting on research related studies to determine the research gaps, then determine the problem formulation, research objectives and research space. The literature review of current food conditions in East Java was carried out through information available on the website of related government agencies. After the problems have been identified, a literature review related to the research was then carried out to find the research gaps. Based on the results of the study, the problem formulation, research objectives and research space were determined. After that, a literature review about theories related to food, food security, simulation concepts, and other theories supporting the research topic was conducted. Lastly, a summary was made about previous research related to the current research and its position.

2.2. Data Collection Phase

Prior to data collection, observations of the research object were first conducted, followed by data collection, which consisted of primary and secondary data. The primary data were obtained from interviews with corn farmers in East Java, chicken farmers (both chicken and laying hens) in East Java and interviews with the feed mill. While secondary data was obtained from related government agencies (Agriculture and Food Security Office of East Java and The East Java Livestock Service).

2.3. Conceptual Model Development Phase

Stage of conceptual model development was done through the description of the conditions. This stage is started with the variables identification to find out the elements that influence the development of the system for commodities. The list of variables is then designed in a causal loop diagram as a form of conceptual model development in dynamic system simulation. In causal loop diagrams, it is easy to understand the causal relationships between variables, namely the positive or negative influence between one variable with another variable, and how is the impact of each variable on other areas. In (National Statistics Center 2019), if a positive feedback loop occurs, it is called a reinforcing loop symbolized by R or a positive sign (+). Whereas if a negative feedback loop occurs it is called a balancing loop symbolized by B or a negative sign (-), which can be known from the multiplication of all positive variables (+) or negative variables (-) which then produce a positive value. After describing the interactions or relationships between variables with causal loop diagrams, then at the stock formulation and flow diagrams, the formulation of interactions or relationships that occur between variables is conducted (Tsolakis and Srai 2017). The main components of the system dynamics approach are the identification of stocks, flows, feedback loops, table functions, and time delays, based on observations and real life literature, e.g. what components influence agricultural profits (Tey et al. 2019). Stock and flow diagrams aimed to catch on an understanding of the interrelationships between variables. Stock depictions indicate the existence of an accumulation between variables, while flow illustrates the level of stock changes in a certain time period.

2.4. Model Verification & Validation

Model verification and validation is a way of testing the model to determine the suitability of the model with the real system. Verification is a process that determines the suitability of the implementation of the conceptual model. This process includes software debugging, searching for inappropriate implementations of the conceptual model and verifying calculations (Kelton and Law 1991). Meanwhile, validation is the process of determining the accuracy of the models representation with real systems and model output is consistent with the output of real systems, several tests for system dynamics models, including boundary adequacy tests and mean comparison testing (Sterman 2000).

3. Result and Discussion

The results of this study consist of the development of causal loop diagram, stock flow diagram, verification and validation model, and simulation results.

3.1. Causal Loop Diagram

In this study, the causal loop diagram consists of four sub-models, namely the sub-models of corn farmers, feed mill, chicken farmers and laying hens farmers. Corn farmers below is one of the sub-models in causal loop diagram, shown in Figure 1.

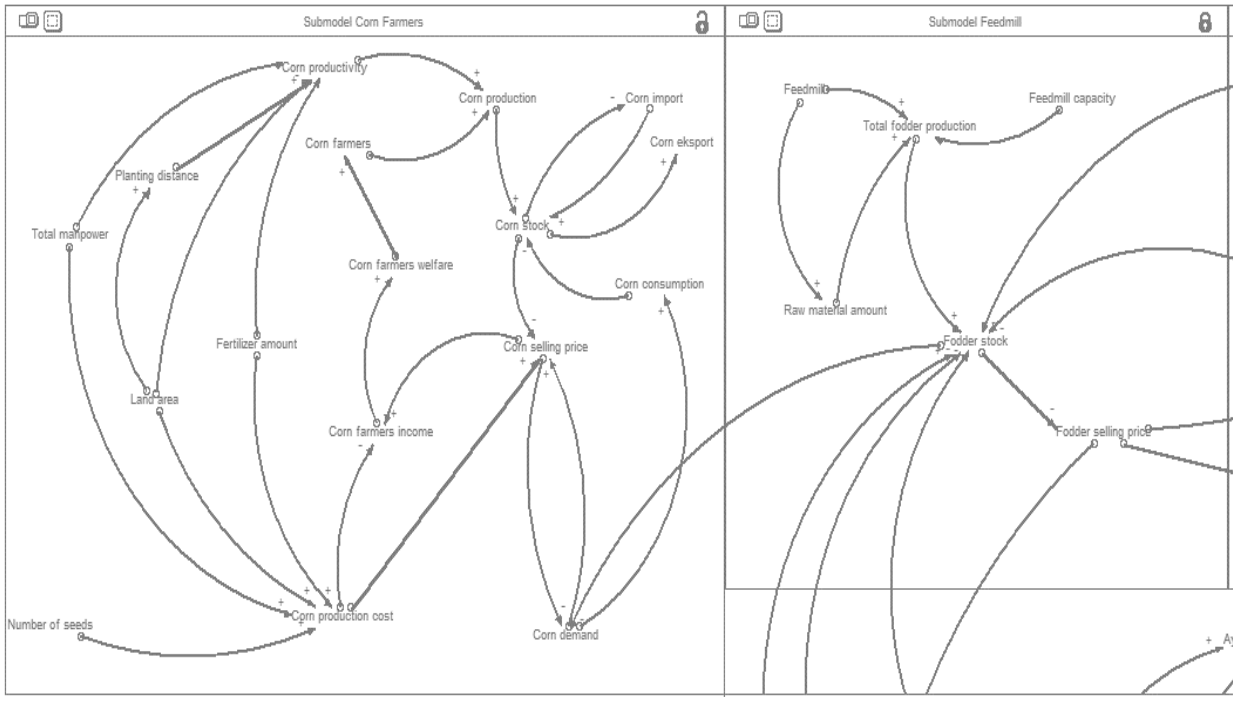

Figure 1. Causal loop diagram sub model corn farmers and feed mill.

In this study, the causal loop diagram consists of four sub-models, namely the sub model of corn farmers, feed mill, chicken farmers and laying hens farmers. The diagram shown is one of the sub-models, namely corn farmers. To have a comprehensive view of all of the four sub-models with respect to one of the variables on each, here is the concluded relationship, shown in Table 3.

Table 3. Causal and impact in each variable.

Sub model	Causal	Impact	Relationship
Corn Farmers	Corn stock	Export	Positive
	Corn stock	Import	Negative
Chicken Farmers	Chicken production	Chicken stock	Positive
	Chicken purchasing price	Chicken demand	Negative
Laying Hens Farmers	Eggs production	Eggs stock	Positive
	Eggs purchasing price	Eggs demand	Negative
Fodder	Fodder production	Fodder stock	Positive
	Fodder stock	Fodder selling price	Negative

3.2. Stock Flow Diagram

The building model in the stock flow diagram consists of four components namely stock (state or level variables), flow (value, control or process variable), converter (translation variable) and connector (information arrow). The system dynamic simulation model consists of a set of nonlinear differential equations, such as the level (or state) equation, flow equation, assist equation, parameter equation, condition equation, and initial value equation (Wei et al. 2012). In the stock flow diagram, the model is broken down into 4 sub-models, namely the sub-models of corn farmers, chicken farmers, laying hens farmers, and fodder for chicken and laying hens. Each identified variable in the sub-models was defined by some formula shown in Table 2.

Table 2. Formula in each variable.

Sub model	Variable	Unit	Formula
Corn Farmers	Corn production	Ton/month	Corn productivity*land area-land area*corn productivity*failure rate
	Corn productivity	Ton/ha-month	(Number of seeds*seed conversion) + (corn farmers ability*corn farmers)
	Land area	Ha	-
	Failure rate	-	-
	Corn farmers ability	Ton/people-ha	-
	Corn farmers	People/month	Corn farmers welfare*farmers conversion due to welfare
Chicken Farmers	Starter broiler consumption	Ton/month	Starter broiler stock*consumption rate per chicken
	Chicken farmers	People/month	Chicken farmers welfare/welfare conversion to farmers
	Chicken farmers welfare	Rupiah/month	Chicken farmers gross income - chicken farmers gross income
	Welfare conversion to farmers	Rupiah/people	-
	Chicken farmers gross income	Rupiah/month	Chicken farmers production cost/value
Laying Hens Farmers	Laying hens farmers	Rupiah/month	Laying hens gross income - laying hens farmers production cost
	Laying hens gross income	Rupiah/month	Laying hens production costs + laying hens production costs*gross income conversion
	Laying hens farmers production cost	Rupiah	(Electricity cost + laying hens fodder cost + manpower cost + other cost + vaccination cost + water cost)*chicken eggs stock
Fodder	Fodder production proportion	Unitless	-
	Feed mill capacity	Ton/month	-
	Fodder price	Rupiah	Fodder stock*fodder price change rate
	Fodder price change rate	Rupiah/ton	-

In the corn farmers sub-model, there are corn stocks that are influenced by several variables, one of them is corn production. Then, corn production is influenced by the corn productivity. Besides, corn stock positively influenced the fodder production by the feed mill. This condition will affect the production costs of chicken and laying hens. Low production costs will increase the net income of farmers and this will encourage an increase in the number of famers, both chicken farmers and laying hens farmers. The stock flow diagram sub model corn farmers can be seen in Figure 2.

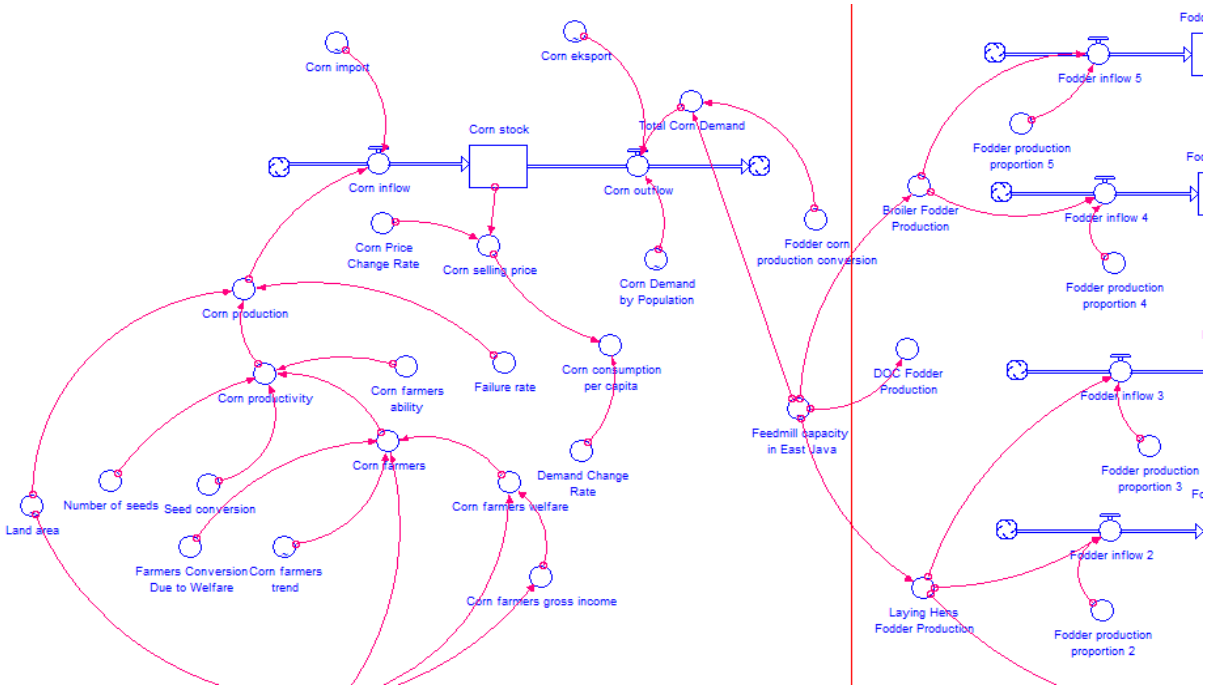

Figure 2. Stock flow diagram sub model corn farmers.

3.3. Verification and Validation

Verification in the STELLA 9.1.3 software was conducted by checking the unit to show that the model has been verified. The unit check results on STELLA 9.1.3 showed that the model has been verified with the appearance of all units within the model appearing to be consistent. Then for model validation, the limitation adequacy test was carried out through literature study from previous research, direct observation on farmers in Blitar and Tulungagung Regency, as well as chicken farmers and laying hens farmers in Blitar Regency, interviewed with the Agriculture and Food Security Office of East Java and The East Java Livestock Service and feed mills. From these results, a causal loop diagram was obtained with the related variables to influence the production of corn, chickens and chicken eggs, and the number of farmers. After that, the validation was done by Mean Absolute Percentage Error (MAPE), with an accepted error limit of 5%. The model is stated to have described the real condition if MAPE <5%, quite right if the value between 5-10% , and wrong if the value is above 10% (Morecroft 2015).

Table 3. Chicken farmers validation.

Month	Simulation (people)	Error	Month	Simulation (people)	Error
1	12.925	0.0180	7	9.525	0.1601
2	11.798	0.1200	8	12.737	0.0350
3	9.172	0.1621	9	10.796	0.1520
4	13.071	0.1291	10	9.935	0.0431
5	12.944	0.0090	11	9.363	0.1360
6	11.344	0.1400	12	12.020	0.0240
Total error					0.09404

Based on Table 3, the error value on the number of chicken farmers is 0.09404 (9%), showing that the model is precise enough to represent the real system.

3.4. Simulation Result

The simulation was carried out with a monthly period for the next 12 months, namely for 2020. The results of the simulation were emphasized on the adequacy of corn to meet the fodder stock, then chicken stock and chicken eggs stock for 12 months. Furthermore, the welfare of farmers also be concerned because the number of farmers support the availability of the commodities.

Figure 3. Number of farmers.

Figure 3 is one of the simulation results, namely for the number of farmers in the next 12 months. Corn farmers number trends to decrease, and finally in December corn farmers will projected to reach 37,940 people. Corn farmers number is positively related to the cost of corn production and the corn selling price at the farm level. If the net income of farmers decreases, the number of corn farmers will decrease. In the same case, chicken farmers and laying hens farmers also tend to decrease. In December, the chicken farmers number became 12,020 people and 696 people for laying hen farmers. This also relates to the income received by farmers.

4. Conclusion

In this research, modelling was designed with causal loop diagrams and stock flow diagrams. Both causal loop diagrams and stock flow diagrams consist of four sub-models. The implication of this research is the resulting model can be used for the East Java government to carry out its food security policy by ensuring the availability of corn as one of the achievement pillars of food security. The policy includes giving instructions to plant corn commodities, at least once a year. Therefore, food stability may also be achieved. In addition, the government can also use the unused land to plant corn and increase corn productivity by implementing a tight spacing system on corn plants in order to increase the corn production.

Meanwhile, other regional governments that produce large corn, such as Central Java, South Sulawesi, and regions that have quite large chicken farmers such as West Java, Central Java, Banten, and North Sumatra can meet the needs of fodder by setting the prices affordable. Thus, this can also encourage the existence of farmers to maintain stable production of chicken and chicken eggs at affordable prices. However, the underlying weakness of this research, emerges in the aspect of parameter assessment of welfare. The corn farmers' welfare was assessed based on merely the selling price of corn and based on the purchase price of fodder for chicken farmers' welfare. In the future it is necessary to assess the welfare indicators more broadly, not only from income. One of them is the approach to understanding human development. In addition, other strategic commodities e.g. soybean as the main source of protein might also be an option for future research.

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