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A Model to Improve Corn Productivity and Production

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Abstract

Corn is a strategic national commodity, because it is a food substitute for rice, raw materials for animal feed, flour, and pharmaceutical. Some problems faced by corn industry include low productivity, less efficient production costs, and production discontinuities. **Therefore, the purpose of this paper is to build and simulate a model to improve corn productivity and production**. **As a method used to build and simulate the model,** we utilized system dynamics based on consideration that problems in land productivity and corn production can be classified in complex systems that may have some feedbacks and requires a system approach for problem solving. **Several factors affecting corn productivity include soil nutrition, planting patterns, corn quality, water availability, disease and pest attacks, as well as the impacts of climate change. Some scenarios have been developed to improve land productivity and production by modifying the model structure.** Simulation results show **that** total harvested area after land expansion would **grow** 0.6% per year, so that total harvested area is projected would be 1.32 M **ha** in 2030. Corn productivity after land intensification is projected to be 73.08 quintals/ha as the impact of structural and non-structural approaches implementation. Total corn production in East Java after land expansion and intensification would achieve 15 M tons in 2030. Meanwhile, the fulfilment ratio in East Java would achieve 1.68 which means that East Java can fulfill its regional demand after land expansion and intensification.

Keywords: corn productivity; production; system dynamics; simulation model; scenarios

1. INTRODUCTION

Corn is a major food commodity besides rice which has a strategic role in agricultural development and national economy of Indonesia. This commodity has an important role in the supply of food and industrial raw materials. It is estimated that more than 58% of domestic corn demand is used for feed, while 30% is used for food, and the rest is for other industrial needs and seeds (Ministry of Agriculture, 2013). Corn demand as raw material for animal feed continues to increase. The use of corn for feed is driven by its relatively affordable price, high calorie content, and is preferred by livestock

compared to other feed ingredients, so that corn remains the main raw material for feed (Kasryno et al., 2008).

Corn is also one of strategic commodities and economic value. **It** has the opportunity to be developed because of its position as the main source of carbohydrate and protein after rice, as well as animal feed industry and raw materials for household use (Direktorat Jendral Bina Produksi Tanaman Pangan, 2002). For the last few years, corn demand continues to increase due to increasing rate of population growth and demand for animal feed. Agricultural cultivation is concentrated in rural areas, but in the presence of urbanization it becomes increasingly difficult to have sufficient agricultural **product** to serve large populations (Emmanuel et al. 2018). Therefore, government makes corn as one of the main food commodities prioritized to be developed. Currently, corn productivity in Indonesia only reaches 4.1 tons per hectare (Asworo, 2015). Compared to several Asian countries, corn productivity in Indonesia is still below some countries, such as Thailand 4.3 tons/ha, Vietnam 4.4 tons/ha, and China 5.2 tons/ha. America is the best corn producer in the world with productivity reaching 9.5 tons/ha**, then followed** by Argentina 7.5 tons/ha and countries joined in the EU with averaged 6.2 tons/ha. Today, Indonesia imports corn around 3 M tons, while national demand is around 8-9 M tons. Production growth averaged 5% per year, while demand growth reached 12% per year (Sembiring, 2015). **To achieve food self-sufficiency in corn industry, Indonesia has planned to add about 1 M ha of corn planting area**. (Sembiring, 2015) to reduce imported corn.

Indonesia still lacks **of** corn production **more or less of** 2-3 M tons per year, if we compare between total national corn production and corn consumption demand that achieved 9 M tons (PT. Benih Inti Suburintani, 2002). To cover the shortage, Indonesia annually imports corn from other countries. According to the Director General of Food Crops (Direktorat Jendral Bina Produksi Tanaman Pangan, 2002), the growth rate of Indonesian corn imports within 11 years (1990 - 2000) continues to increase with an average growth of 12.99 % per year. This is a challenge for the Ministry of Agriculture, in order to reduce the dependence of imported corn.

One of the problems in corn production is marketing that is concentrated in several regions in Indonesia such as Java and Sumatera (Muladno, 2015). Some problems faced by national corn industry (Purba, 2016) include: 1) low average national productivity that has not been able to penetrate six (6) tons / ha, 2)less efficient production costs, 3)production discontinuities, and 4) production sites that are not close to market location, especially feed industry location. The location of corn production centers that not close to the location of feed industry, resulting in high distribution costs that affect the corn price in consumers site. Currently, some problems in the cultivation of corn plants that cause low productivity and crops (Pulungan, 2017) include:

a. Land condition that has been critical and poor in soil nutrients:

Food cropland in Java often uses inorganic chemical fertilizers, resulting in poorer soil nutrients and many dead soil microorganisms. The impact of **this misuse** is that the soil becomes more acidic, needs liming, and soil reconditioning treatment with organic fertilizer. National agriculture has been trapped in fertilizing inorganic chemicals which have an impact on the acceleration of agricultural land fertility degradation. This happens because the culture of **using** chemical fertilizers in a long time, which is not a good way if there is no effort to fertilize with organic elements in the long run. Another thing that causes the use of chemical fertilizers is the construction of several chemical fertilizer factories by Government, so that their production needs to be absorbed by farmers. As a result, agricultural land becomes very critical and poor in soil nutrients, which has an impact on low crop productivity and decreased power of plant immunization which results in pest attacks on corn crops. With so many plant disease pests, farmers will need insecticides which cause higher production costs and damage the qualification of crop production.

b. Unbalanced fertilization method

Balanced fertilization is always required in the processing of agricultural land. Nutrients that are in the soil, will gradually diminish because they are absorbed by the plants along with the harvest besides heating and evaporation. Land management and integrated soil nutrient processing will increase the effectiveness of nutrient provision, and will maintain soil quality in order to continue to function sustainably. Fertilization can be done with chemical fertilizers (inorganic) or non-chemical fertilizers (organic). **In the short term**, chemical fertilizers will accelerate the planting period because the ingredients can be absorbed directly by the soil and plants, but on the other hand, if the use of chemical fertilizers in the long run, it will have a very negative impact on the soil and plants. The main objective of proper and balanced fertilization is to ensure optimum nutrient availability to support plant growth so as to increase the expected yield. The efficient use of fertilizers is basically to provide fertilizer in the form and amount that suits the plant demand, in the right way and at the right time according to the needs and growth rate of the plant. Plants can use fertilizers optimally only in active roots, but **very** difficult to absorb nutrients from dry or dense soil layers.

Fertilization efficiency can be estimated and predicted based on the increase in plant dry weight.

In general, plants cannot fully absorb 100% of inorganic chemical fertilizers (Pulungan, 2017). There will always be residues that are not absorbed. In terms of fertilization, many farmers think that by giving fertilizer more than the amount, the production will increase. This is a wrong opinion, because the remnants of chemical fertilizers left in this soil, if they have been exposed to water for a long period, there will be a process of binding the soil like glue. As a result, there will be drought and adhesions that condense one another, so that the soil becomes loose, hardens, and increases its acidity. This condition will make soil fertilizing organisms die or decrease in population. If this happens for a long time, then the land will get thinner and the dependence on chemical fertilizers will increase. The provision of nutrients is to improve soil conditions, whether physical, chemical or biological, which is called soil improvement. Manure and forage, compost, liquid organic fertilizer can be mixed into the soil so that the fertilization process becomes balanced and can improve the condition of agricultural land. Currently, most of the farmers have not applied the principle of fertilization based on the recommendations so that land productivity is not optimal.

Another problem in terms of fertilization is the limited capital and the availability of fertilizer on time and the right amount. In terms of capital, most corn farmers still use their own capital, there is no support from banks or other capital institutions. As a result, farmers cultivate according to their financial capabilities. Meanwhile, in a number of areas the distribution of fertilizers is still not smooth, so fertilizer is often not available when required. **This causes the productivity of corn at farm level is still low**.

c. Unavailability of seeds at the farmer level

In terms of seeds procurement, the government always provides seeds based on the regional demand with prices following the government's provisions. As a result, there is a qualification for seeds that do not match the qualifications of superior seeds. The problem in the distribution of quality seeds is the unavailability of seeds at the farm level in accordance with the planting time and the price of high-quality superior seeds. The low level of use of hybrid seeds is also one of the causes of **low corn production**. Currently, the potential of hybrid corn productivity reaches 7-12 tons / ha, and composite superior corn is 5-7 tons / ha [9], while the national productivity average has only reached 4.23 tons / ha (Statistics Indonesia, 2008).

Based on the above problems, it is necessary to improve corn productivity and production through land intensification and expansion. Land expansion can be done through the development of new agricultural land to untapped areas such as forest land, dry land, or peatlands. Meanwhile, land intensification is designed to improve land productivity by conducting rehabilitation of watersheds and irrigation network, the implementation of new technology, strict rules of land conversion, dynamic cropping calendar, dissemination of climate information, the development of climate field schools.

The increase in corn production is not only to meet high domestic demand, but also to fill opportunities in the world market because the demand for corn globally and regionally is also high and continues to increase. Increased productivity and production can take place in various agroecosystems ranging from high productivity environments to low productivity environments (BPTP Balitbangtan Sulsel, 2018). For this reason, it is necessary to have corn production technology that can adapt to various environments. The integration in production technology component is expected to increase corn productivity and production. The benefit of developing corn production in dry season is important to overcome the corn supply deficit as well as to increase corn farmers' income in the dry season due to relatively high prices.

Several factors that contribute to corn productivity include weather, soil type, pests, diseases, farm-management practices, choice of weed, insect- and pest-control methods, planting density, tillage type, planting date, and the amount and dates of fertilizer applications (Smith & Kurtz, 2015). Corn production can be improved by enhancing planting methods, providing technologies, fertilizers, and efficient human resources in order to decrease imports and to narrow the gap between corn demand and supply (Khodeir, M. H., & Abdelsalam, 2016). Agricultural production systems such as crops, livestock, and an integrated crops and livestock are consisted of multidimensional components and drivers that interact in complex systems to influence production sustainability (Archer et al., 2016). The systemic interaction will influence the economic, environmental, and social sustainability of agricultural production. The result from system dynamics modelling found that the greatest potential for sustainability existed with the crops only production system. Corn production is so strongly seasonal, harvested corn accumulates in the fall and is depleted over the course of the year until the next harvest (Conrad, 2004). There are various factors that influence the decision to utilize agricultural land in an area. The factors can be physical and non-physical factors (Erviyana, 2014):

1. Physical factors affecting agricultural land productivity which include:
    a. Climate; temperature (heat) and rainfall (Kawasaki and H. Srikantha, 2011);
    b. Topography; relief and rocks;
    c. Soil; nutrient / fertility elements and soil physical properties;
    d. Water; potential water, depth (Klocke and Currie, 2011)
2. Human Factors (non-physical factors) which include:
    a. Skill level of labor;
    b. Farmers' technological capabilities (education, science, experience and management);
    c. total farm labor

Several factors affected farming productivity are social and economic factors that include labor, capital, technology, markets and government; and environmental factors which include climate, relief and soil (Revisionworld, 2018).

a. Labor: farmers use abundant cheap labor instead of machines. People working on farms may be unskilled labors or skilled and able to use machinery, such as tractors, harvesters.
b. Capital: the money the farmer has to invest in the farm, can be used to increase the amount of inputs into the farm, such as machinery, fences, seeds, and fertilizer. If a farmer can afford to invest capital, yields will rise and can create greater profits which can be used for more investment.
c. Technology: machines and irrigation are two types of technology that can increase corn yields. Greenhouses, with computer-controlled technology, provide ideal conditions for high quality crops. Computer can control the temperature, moisture level, and amount of feed for the plants. Genetic engineering has allowed new plants to be bred that resist drought and disease and give higher yields of corn.
d. Markets: farmers grow crops which are in demand and change to meet new demands. Markets vary throughout the year and farmers change their production to suit them.
e. Government: they influence the crops farmers grow through regulations, subsidies and quotas. Government may offer advice, training, and finance to farmers and, in new farming areas, may build the infrastructure of roads and drainage.

f. Climate: temperature (minimum 6°C for crops to grow) and rainfall (at least 250mm to 500mm) influence the types of crops that can be grown, e.g. hot, wet tropical areas favor rice. The length of the growing season also influences the crops grown.

g. Relief: Lowlands, such as flood plains, are good for crops. Temperature decreases by 6.5°C for every 1000 meters gained in height, more gentle slopes are less prone to soil erosion.

h. Soil: fertility is important; poor soil means lower outputs, so that it will require larger inputs of fertilizers. Good drainage can reduce the dangers of waterlogging.

The opportunity to increase national corn production through increased productivity, especially through the use of improved varieties, balanced fertilization, and improved management is still quite large (Sudana, 2005). Possible efforts can be done to improve the corn production in the region (Java, Bali, Madura and Nusa Tenggara) is through intensification by using hybrid superior varieties and other management improvements such as the use of balanced fertilizer dose, as well as time and appropriate manner in accordance with the conditions and chemical properties of local land. This effort has a great opportunity to be implemented to improve corn productivity. The productivity in several areas during the last eleven years is still relatively low such as in Java and Madura with the average 2.3 tons/ha and 2.0 tons/ha in Bali & Nusa Tenggara, while the growth per year is also relatively low, which was around 2.93 and 1.83% respectively. The future challenge is how to fulfill the corn demand for feed raw materials, food, and energy (Zakaria, 2011). The potential for corn development is still very large, through the expansion of planting areas, increasing productivity by using new improved varieties, applying innovative cultivation technology with Integrated Crop Management approach, securing production from attack of plant disturbing organisms, as well as post harvest handling.

To improve corn productivity and production as well as to adapt to climate change, we utilized system dynamics model based on some considerations of its advantages (Turner, et al., 2016): a) system dynamics is a systems thinking approach to address agriculture and natural resources issues in multi- and interdisciplinary aspects; b) provides a holistic perspective to accommodate all problem elements; c) facilitates qualitative and quantitative techniques to incorporate "soft" and "hard" elements required for analyses. We have developed a set of models and analyzed corn productivity and production based on existing condition. A causal loop diagram (CLD) is required as the basic building block in developing system dynamics model. CLD provides qualitative and quantitative insights in sensitivity analysis, highlighting the

dynamic influences of social quality driver would likely be the most influential on production system sustainability and success (Archer et al., 2016). The dynamic information provides rich insight into the aspects that cause potentially reinforcing feedback behavior or stabilizing balancing behavior. This paper is designed to make a novel contribution in corn industry sector by developing a system dynamics model to learn about the system behavior of corn productivity and production. The questions that guided this research were:

1. What drivers influence corn productivity and production?
2. What efforts should be made in adapting to climate change in order to maintain and increase corn productivity?
3. How do these drivers systemically and dynamically interact to influence corn production?
4. How to project corn demand in the future?
5. How to improve corn productivity and production through land intensification and expansion?
6. How to increase corn fulfillment ratio by considering the future demand?

To answer these research questions and accomplish our study objective, a system dynamics modelling is utilized because of its user-friendly interface, and widely recognized modelling iconography. We demonstrate a set of model of harvested area, corn productivity, and production based on existing condition to learn about the system behavior. To check the model accuracy, we conducted structural and behavioral validation. Once the model valid, we may utilize the valid model to develop scenarios to increase corn productivity and production. Scenario can be developed by adding some feedback loops and new parameters as well as changing the structure of the feedback loops. In this research we have developed three scenarios, those are: 1) land expansion scenario; 2) land intensification scenario; 3) land expansion and intensification scenario.

This paper is organized as follows. Section 2 provides the research method consisting of system dynamics framework, problem formulation, causal loop diagram development, stock and flow diagram development, model validation, and scenario development. Section 3 describes results and analysis. Finally, in section 4 conclusion and further research required are presented.

2. RESEARCH METHOD

This section demonstrates research method that includes the development of dynamic simulation model consisting of system dynamics framework, problem formulation, causal loop diagram development, stock and flow diagram development, model validation, and scenario development.

2.1. System Dynamics Framework

Problems in land resources such as land transformation, land productivity, soil quality, and soil erosion (Mahmood, et al., 2014) - (Kumari, 2015), agriculture challenges, and food systems can be classified in complex systems, because in such systems many have interacting feedback, which requires a system approach to problem solving, including strategies to increase agriculture productivity as well as to improve systems and resource integration (Liu et al., 2015). The complex system has the following characteristics: (a) the observed behavior is dynamic; (b) the existence of some causal relationships and feedback on the system; (c) involves many variables (Cilliers et al., 2013).

System dynamics is a framework that deals with several complex systems which consist of nonlinear feedback characteristics (Sterman, 2000). System dynamics has focused on qualitative methods and quantitative techniques through computer programming and simulation, emphasizing stakeholder engagement to define mental models of a complex system. We might use a nonlinear mental model to address and describe the dynamics problem of feedback process. System dynamics has proven to be useful in overcoming problems in terms of land transformation, land productivity, soil quality, and soil erosion. The purpose of this study is to implement system dynamics modeling methodology in improving corn productivity and production. System dynamics is essentially an interdisciplinary science consisting of several scientific disciplines, based on the theory of nonlinear dynamics and feedback control, referring to cognitive and social psychology, economics, and other social sciences to incorporate human resource dimension and decision making (Sterman, 2000). There are five steps in implementing system dynamics simulation model (Sterman, 2000), those are:

1. Problem formulation: this stage describes the underlying mechanisms of the problem (Goodman, 2006) through interviews with stakeholders, surveys, forum group discussion, and data collection to illustrate the system behavior. In this step we need to determine the boundaries, variables, time horizons, and data sources. Some activities include: interviews/surveys, describing mental models, collecting/aggregating reference mode of data.

2. Dynamic hypothesis: this hypothesis synthesizes all problems to evaluate the quantitative model. We need to define the input for decision-making and mental models as the root causes of the problem (Sterman, 2000) – (Lane, 2000). This steps represents the initial explanation of the endogenous dynamics of the problem. Some activities include: identify current theories of the problem; causal loop diagram development; and stock-and-flow development.
3. Simulation model development: the model construction is supported by computer programming consisting of several variables such as stock, flow, auxiliary, as well as material and information flows. This stage emphasizes on the determination of system equations, objectives, and constraints. Some activities include specifying model structure, decision rules; parameter estimation and setting initial conditions; **as well as** checking model consistency with dynamic hypothesis.
4. Model validation: this process is required to test the model with extreme conditions and parameter values and to find out whether the assumed parameter values and model responses match the feedback polarity, as well as to check the consistency of the model. This step emphasizes on building confidence in the quantitative model. Several activities include: reference mode comparisons; extreme condition testing; as well as sensitivity analyses.
5. Scenario (experimentation) development: this step involves asking and applying "what if?" questions to the model based on the proposed strategy or policy interventions. Several activities include: scenario design and analysis; stakeholder outreach.

Figure 1 represents the mechanism of system dynamics variables which consists of stock, flow, auxiliary, as well as material and information flows (Turner et al., 2116).

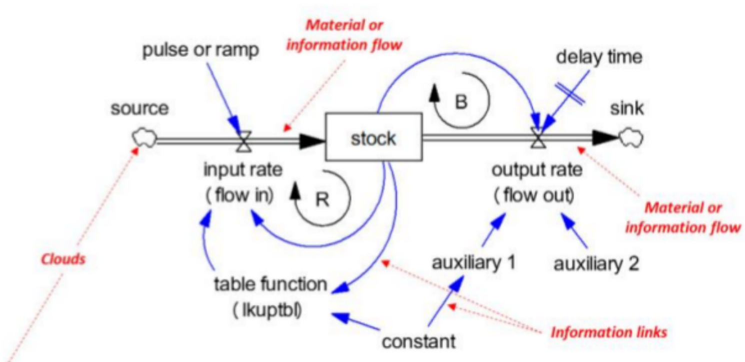

Figure 1. System dynamics variables (Turner et al., 2116)

2.2. Problem Formulation

Agricultural productivity is the output of agriculture in terms of inputs such as capital and labor (Johnston, 2007). Corn commodity has a strategic utility, both in terms of food security and its role in national economic. Corn is used for food, feed, fuel, and polymer. Corn demand for food, feed and other industries will increase in line with the population growth. Physical factors are some important factors in determining agricultural productivity. Agricultural land with good conditions can have higher productivity. This productivity is one of several factors that affect agricultural production besides of the harvested area, rendement, and adaptation to climate change. Harvested area is affected by the area of corn planting, the intensity of planting, and puso. Meanwhile, the land area is affected by the expansion of new land and the rate of land conversion (Hasan, 2010). Puso is a condition where a crop does not produce, due to damage caused by pests (plant-disturbing organisms) and the impacts of climate change such as floods, droughts, landslides, volcanoes, strong winds, and disasters. Corn rendement represents the depreciation of corn product percentage after threshing process. This rendement is obtained by comparing the initial weight with the final weight before and after threshing process. Rendement is influenced by agronomic nature of each variety, including seed weight, seed quality, harvest age (physiological cooking), and seed type (Suarni et al., 2013).

In terms of national corn production, Indonesia has four problems (Purba, 2016) covering: 1) the average national productivity that has not been able to penetrate 6 tons/ha; 2) the lack of efficient production cost, discontinuity in production, and location of production not close to market location, especially location of feed industry. Around 50% of corn demand in the feed industry relies on imports; 3) the postharvest handling, limited postharvest handling facilities, engineering and silos, resulting in low quality of local corn; 4) marketing is still constrained by the length of supply chain from producer to consumer.

In this research, we focus on corn productivity and production improvement base on several consideration as follows: 1) corn has become a basic need for daily consumption; 2) corn plant is not difficult to cultivate, even quite easy compared to planting vegetables or any other plant; 3) corn demand is high enough as the population increases.

2.3. Causal Loop Diagram Development

Causal loop diagram (CLD) development is the basic framework used in developing system dynamics simulation model. CLD describes the causal mechanisms underlying the dynamic hypothesis of system behavior over time, as the impact of the feedback structures (Sterman, 2000). In addition, CLD was developed for the purpose of describing the system in detail and to conduct policy analysis (Homer & Oliva, 2001). A causal loop diagram consists of several basic elements such as the variables, the links between variables, the signs on the links, and the sign of the loop that shows the type of system's behavior (Lannon, 2018). Several factors affecting corn productivity include soil nutrition, planting patterns, corn quality, water availability for ditch irrigation, disease and pest attacks, as well as the impacts of climate change such as rainfall and air temperature. This climate change can be affected by (Aldrian,2008) : 1) ENSO (El Nino / La Nina and Southern Oscillation) which is a global phenomenon of atmospheric ocean that brings the sea implications of Indonesia cooler in the event of El Nino and warmer in the event of La Nina, 2) sea surface conditions, 3) changes in rain patterns, and 4) increase in air temperature. The causal loop diagram of corn productivity and production can be seen in Figure 2. As we can see from Figure 2, productivity is closely related to corn production. Several factors affecting corn production include the area of corn harvest, rendement, corn productivity, and the adaptation to climate change. In the case of the area of corn harvest, several factors such as land area, the intensity of cultivation, and puso will affect the area of corn harvest. There are several factors that could affect the land area, those are the expansion of new land and the rate of land conversion. Puso is a condition where a crop does not produce, due to damage caused by pests (plant-disturbing organisms) and the impacts of climate change such as drought, flood, landslide, volcano eruption, strong winds, and other disasters. Corn rendement is the percentage of corn yield obtained from the initial weight with the final weight before and after threshing process. Rendement is influenced by the agronomic nature of each variety, including seed weight, seed quality, harvest age (mature psychologically), and seed type (Suarni et al., 2013). Adaptation to climate change should be carried out to anticipate the occurrence of puso. Such adaptation can be conducted through structural and non-structural approaches (BAPPENAS, 2014). Structural approach can be done through the rehabilitation of irrigation network and watershed. Meanwhile, non-structural approach is conducted through the implementation of new technology in the process of planting corn, making strict rules on conversion of corn planting area, the development of dynamic planting calendar, dissemination of information about climate, as well as the development of climate field school. Non-structural approaches are strongly influenced by farmers' adaptive capacity to climate change. The causal loop diagram of the adaptation to climate change can be seen in Figure 3.

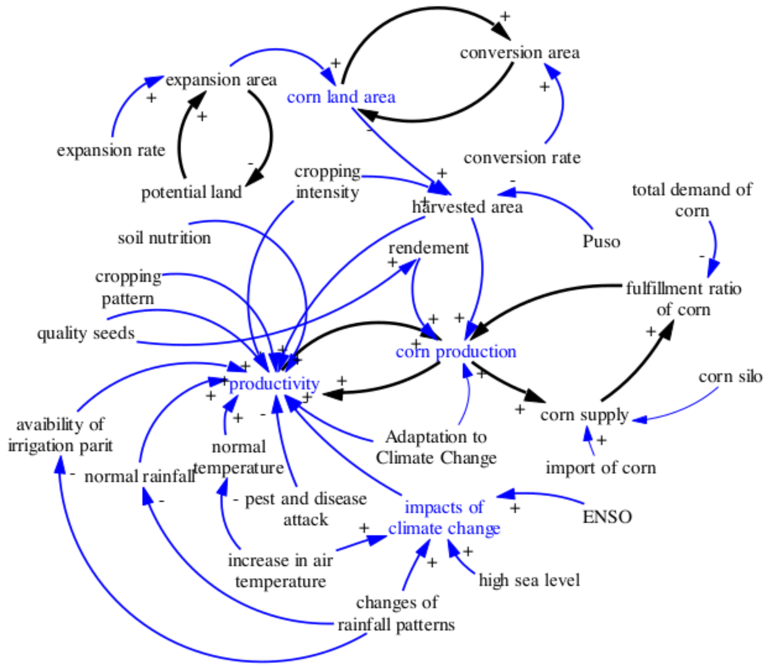

Figure 2. The causal loop diagram of corn productivity and production

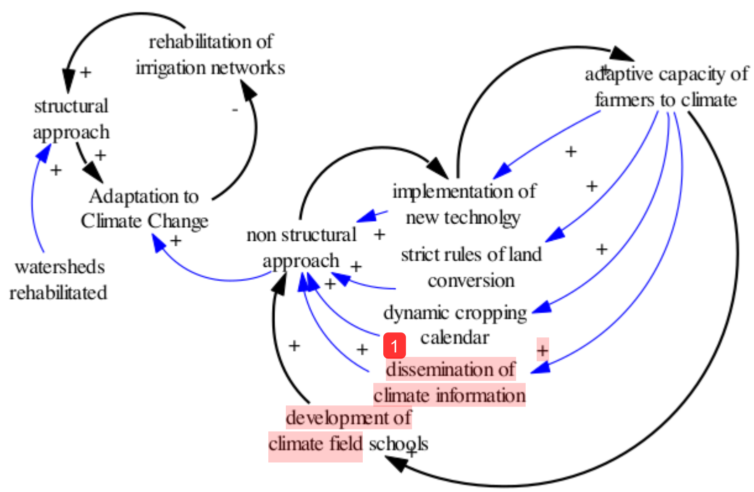

Figure 3. The causal loop diagram of climate change adaptation

2.4. Stock and Flow Diagram Development

A stock and flow diagram demonstrates a calculable representation of a system. In this phase, each variable must be defined and assigned the correct units, and mostly new variables must be added to the stock and flow diagram (Aronson and Angelaki, 2018). After we develop the

CLD, the next step is converting the CLD into stock and flow diagram. From the CLD, we need to determine which variables in CLD are **stocks**. Based on the CLD, we can determine several stock and flow diagrams for each submodel, **that can be described as follows**:

2.4.1 Harvested Area

Total harvested area is the summation of several harvested areas in some regions as seen in Figure 4. Model formulation for harvested area based on the existing condition can be seen in Eq. 1-7.

corn land area = Initial corn land area + ∫ 〚expansion area-conversion area〛 (1)

expansion area = corn land area *expansion rate (2)

conversion area = conversion rate*corn land area (3)

harvested area = corn planting area - (corn planting area *puso area) (4)

puso area = RANDOM UNIFORM (0.028, 0.04 , 1) (5)

corn planting area = Cropping intensity*corn land area (6)

$$Total\ harvested\ areas = \sum_{i=1}^{n} harvested\ area\ (i) \quad (7)$$

Where:

n = the number of corn farming areas

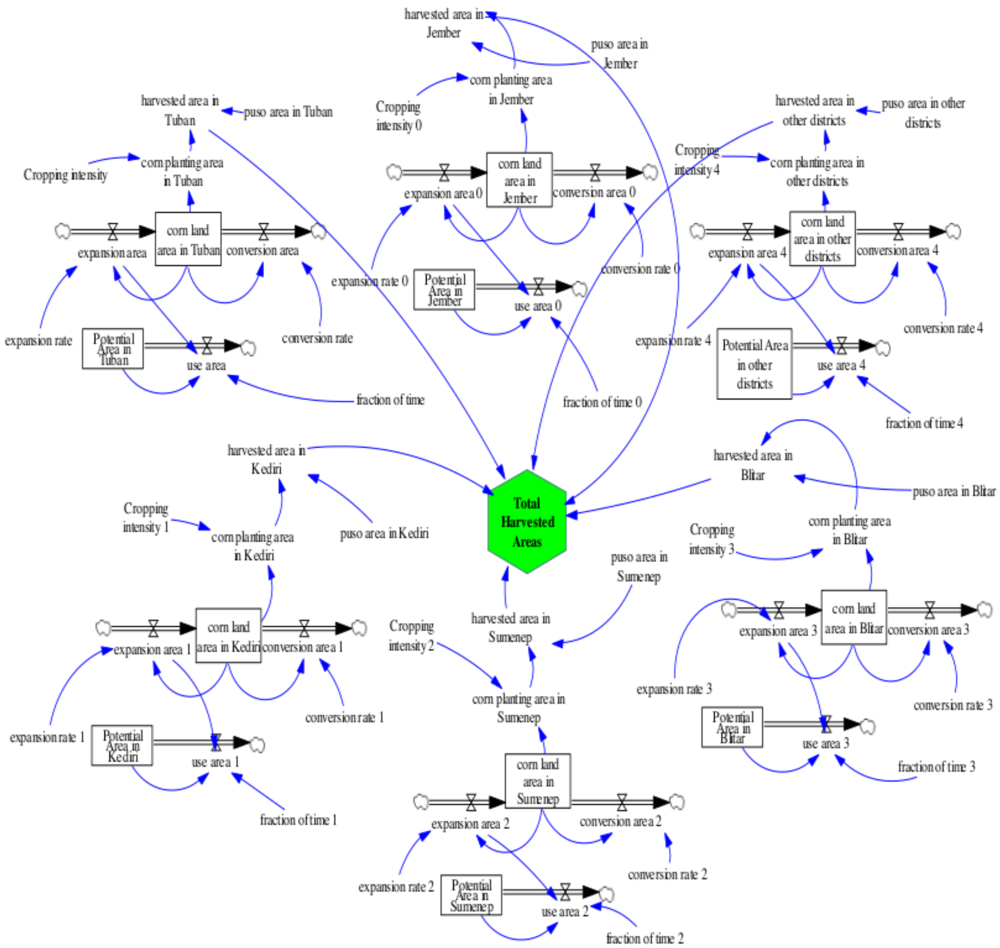

Figure 1. Stock and flow diagram for total harvested areas

2.4.2 Corn Productivity and Production

Stock and flow diagram of corn productivity and production can be seen in Figure 5. We define productivity as a level variable based on consideration that the value of land productivity is the accumulation of productivity from time to time. Model formulation for corn productivity and production can be seen in Eq. 8-12.

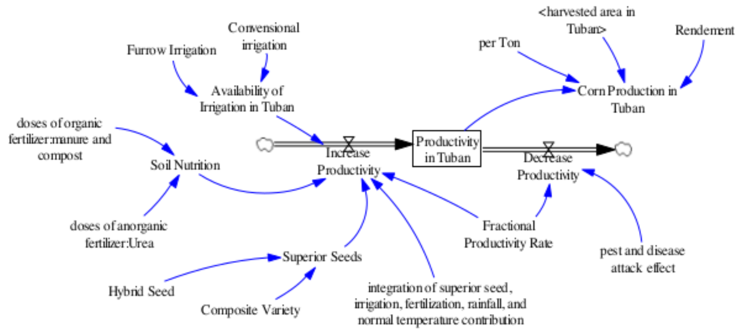

Figure 5. Stock and flow diagram of corn productivity and production

Productivity = Initial productivity + ∫ 〚Increase Productivity- Decrease Productivity〛 (8)

Increase Productivity =

((Avaibility of Irrigation + Soil Nutrition + Superior Seeds +"integration of superior seed, irrigation, fertilization, rainfall, and normal temperature contribution") * Fractional Productivity Rate) (9)

Decrease Productivity = pest and disease attack effect * Fractional Productivity Rate (10)

Corn Production = ((harvested area * Productivity)/10)* Rendement (11)

Fractional Productivity Rate = RANDOM NORMAL (48.02, 54.02, 50.57, 1.268, 1) (12)

2.5 Model Validation

Model validation is required to the model accuracy and constitutes a very important step in system dynamics simulation model development. **In general, model validation consists of two types of validity test (Barlas, 1989):**

a. **Structural validity tests: to check whether the model structure has an adequate representation of the real structure.**
b. **Behavior validity tests: to check if the model can provide an acceptable output behavior.**

2.5.1 Structural Validity Tests

Structure validation means that the relationships built into the model can represent relationships in real systems which can be done in two ways: direct structure and indirect structure testing. Direct structure testing can be done by assessing the validity of the model structure by comparing the model directly with the knowledge of real structure (Barlas & Kanar, 1997). Meanwhile indirect structure test means applying

certain behavior test on the model (Barlas, 1989). The appropriate structures consist of logical formulations and causal structures. The right structure for the right system behavior becomes core of the validation process (Qudrat-ullah, 2012).

The design of the conceptual model in the form of Causal Loop Diagram (CLD) must be structurally validated before it is converted into stock and flow diagram (SFD), so that a model structure in CLD is more relevant, credible, and fit with the actual system observed (Qudrat, 2005). The first step in CLD development is to formulate a problem by accurately identifying causal relationships in the system (Pidd, 2010). The validated CLD is then converted to SFD by involving all stakeholders consisting of modelers, users, policy researchers, and system analysis. It is necessary to identify the right structure and behavior to make the appropriate logical formulations to create a high model credibility (Kleindorfer & Ganeshan, 1993). Structure validation can be done by using five structural validity tests which consist of: 1) Boundary adequacy, 2) Structure verification, 3) Dimensional consistency, 4) Verification parameters, 5) Extreme condition, as illustrated in Table 1 (Qudrat & BaekSeo, 2010).

Table 1. Type of test in structural validity of a system dynamics simulation model

Type of Test	Purpose of the test
Boundary adequacy	Whether the important concepts and structures to address the policy issues are endogenous?
Structure verification	Whether the structure is consistent with relevant descriptive knowledge in real system?
Dimensional consistency	Whether each equation dimensionally corresponds to the real system?
Parameter verification	Whether the model parameters are consistent with relevant knowledge in real system?
Extreme condition	Whether the model shows a logical behavior when selected parameters are designed extreme values?

In this study, the model purpose is to analyze the system components that influence corn productivity and adaptation activities carried out in the agricultural sector in order to adapt to climate change which is always changing at any time, thus giving an impact towards corn production. Four sectors have been identified as the basic building block in CLD development as shown in Figure 6. These four sectors are written in blue fonts for further clarity, which can be explained as follows:

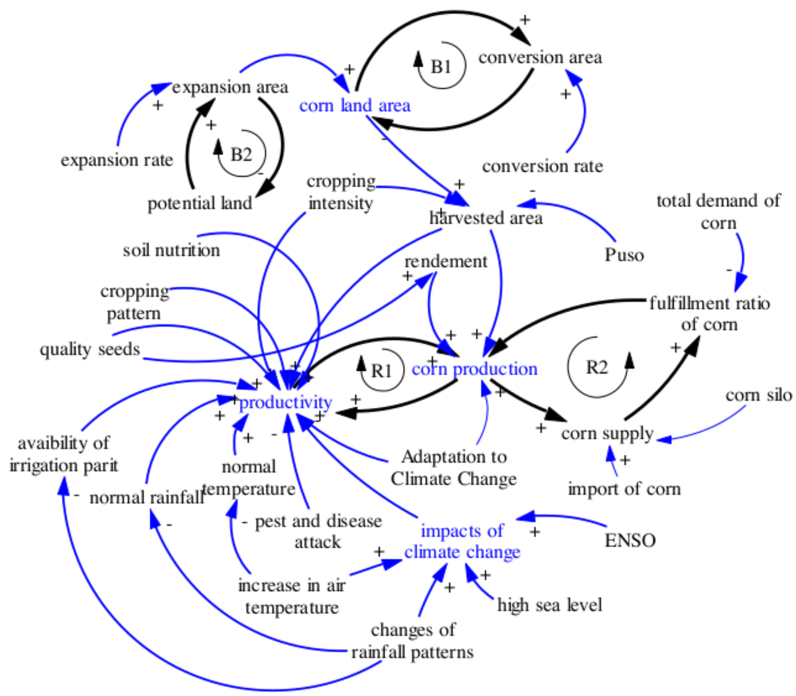

Figure 6. Causal Loop Diagram of Corn Production and Several Feedback Loops

1. **Land Area Sector: this sector explains the component of land area for corn cultivation which is influenced by government policies in the efforts to land expansion, especially by utilizing potential land that is temporarily not functioning, such as plantation and forest lands, and the impact of land conversion for settlement and road construction which can reduce the planting area, thus affecting the quantity of corn harvest area.**
2. **Production Sector: corn production is influenced by several factors including rendement, adaptability of corn farmers to climate change, harvest area, intensity of planting, and puso (a situation where a crop cannot produce due to damage caused by plant pest organisms).**
3. **Productivity Sector: productivity is determined by several components such as rainfall, 2) soil nutrition, 3) cropping patterns, 4) seed quality, 5) irrigation, 6) temperature; 7) pest and plant hopper attacks**.
4. **Agriculture Sector as an Impact of Climate Change: this sector provides information about the impact of climate change on corn productivity which is influenced by the global phenomenon of the sea, namely El Nino / La Nina and Southern Oscillation (ENSO) which has an impact on weather in most tropical**

regions and subtropics. high sea level which has the potential to cause shrinking agricultural land, changes in rainfall patterns, and rising air temperatures.

After identifying several sectors that form the basis of CLD development, the next process is structural validation of the CLD conceptual model. Several tests are developed to make the model more relevant and credible (Qudrat, 2012). This test begins with the development of conceptual model of policy issues based on data and specific expertise to carry out the boundary adequacy tests and structure verification. After these two tests, the next process is to create a mathematical model, inputting the specific data to apply the dimensional consistency test and parameter verification. For the operational model, a specific structure test is utilized such as the extreme condition test to improve the model structure. All structural validation tests can be seen in Figure 7.

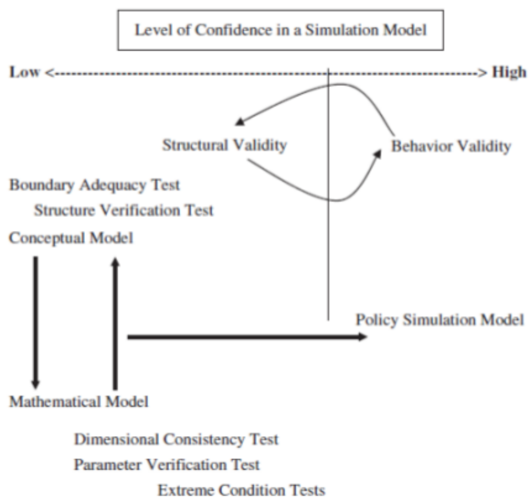

Figure 7. The process of testing structural validity (Qudrat & Seong, 2010)

a. Boundary Adequacy Test: in this test the boundaries of variables are determined as endogenous variables and exogenous variables that form the structure of the conceptual model of corn production. The model structure of corn production must be consistent and relevant to the real knowledge of corn production process.
    - CLD for productivity and corn production: the endogenous variable is an intensification system component which means the efforts to increase the value of corn production without expanding the existing planting area. Intensification is carried out by increasing productivity through

the use of superior seeds, fertilizers, irrigation, maintenance of soil nutrients, rendement, counseling on the appropriate planting patterns, counseling on adaptation to climate change adaptation, and counseling to prevent attacks of plant diseases and pests. Meanwhile, the exogenous variables are system components which represent the efforts to increase corn production by expanding corn planting areas through agricultural land expansion to potential land that has not been functioned as well as limiting land conversion through government policies. This land conversion will reduce the harvest area.

- CLD for climate change adaptation: the endogenous variable is a non-structural approach which represents an effort to increase the capacity of corn farmers to climate change through counseling and government policies such as the application of new technologies for agriculture, strict land conversion rules, dynamic planting calendars, spread climate information in real time, and the development of a climate field school organized by the Agency for Meteorology, Climatology and Geophysics (BMKG) which aims to provide knowledge for officers and farmers to increase their understanding of climate information. While the exogenous variable is a structural approach which represent an effort made by the local government to maintain or increase the intensity of corn planting. The form of adaptation includes climate change adaptation through the management of natural infrastructure such as rehabilitation of irrigation and watersheds.

b. Structure Verification Test: this test is very crucial in the whole validation process. The causal relationship developed in conceptual model is based on the available knowledge in real system. The sub model adopted from the existing domain model becomes the basis theoretical structural validation (Jiang & Fang, 2014). In the CLD of corn production and climate change adaptation, structure verification test was carried out with two approaches. The first approach has been conducted during the construction of the conceptual model by using a specific data and available knowledge about the real system of corn production. Meanwhile, the second approach has been done in the modelling phase by referring to the CLD that is aligned with the real system. Conceptually, corn production depends on productivity, area of harvest, adaptation to climate change, and rendement. Corn productivity is determined by several components including; 1) soil nutrition; 2) the pattern of planting corn; 3) the availability of irrigation; 4) seed quality; 5) rainfall patterns; 6) temperature: corn can grow well at 25ºC-35ºC; 7) pests that commonly interfere with corn planting; 8) rendement which represents the ratio of initial weight of seed material to the final weight ; 9) the adaptation of corn farmers to reduce or avoid the effects of climate change due to seasonal shifts and changes in rainfall patterns.

In addition to support this test, we have defined several feedback loops in the CLD of corn production (Figure 6) consisting of two balancing feedback loops (B1 and B2) and two reinforcing loops (R1 and R2) that can be described as follows:

1. B1 - loop: conversion rate - corn land area: conversion area results in a reduction in corn land area.
2. B2 - loop: expansion area - potential land: expansion area will decrease the potential land.
3. R1 - loop: productivity – corn production: the higher productivity results in the increase in corn production.
4. R2 - loop: corn production – corn supply – fulfillment ratio: the higher corn production results in the increase in corn supply and fulfillment ratio.

Climate change adaptation can be done through structural and non-structural approach as seen in Figure 8. The integration of these two approaches emphasizes on the balance of ecosystems, especially in utilizing water resources by considering several factors such as location, time, and environmental quality. Structural approach can be done through rehabilitation of irrigation networks in order to streamline the use of water resources, to support the stabilization of food security, and to increase productivity. Meanwhile, non-structural approach can be carried out in several ways, such as 1) the application of new technologies, for example the use of superior seeds that are adaptive to drought, inundation or flooding; 2) strict regulations on land conversion must be made by local government, because land use change (unplanned urbanization) in the downstream and upstream areas of the river causes the reduction in water storage capacity. The reduction in water storage capacity will cause flooding on corn planting land when climate change occurs with high rainfall; 3) integrated planting calendar that provides information on potential cropping patterns, planting times, potential planting area, and recommendations for adaptive technology at the provincial level up to the sub-district level; 4) climate information dissemination to minimize risk due to climate; 5) climate field school that is expected to enable corn farmers to apply climate forecast information and be able to adapt to farm management when extreme climate change occurs.

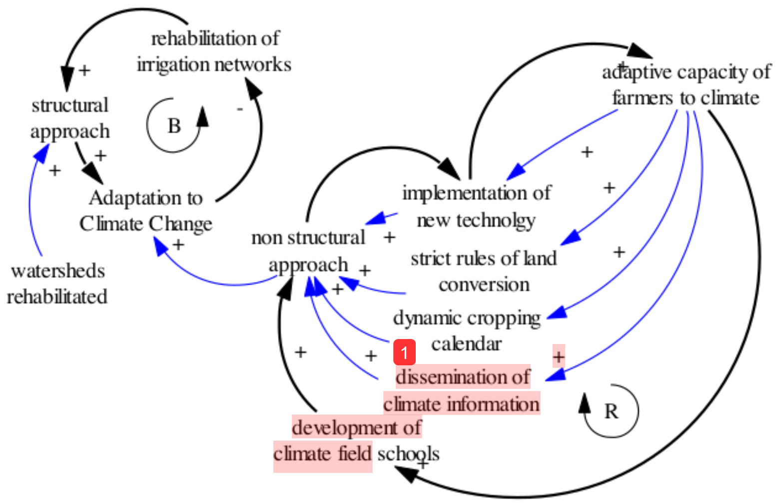

Figure 8. CLD of the Adaptation to Climate Change and Several Feedback Loops

With reference to Figure 8, it can be seen that there are two loops feedback consisting of one loop balancing (B) and one loop reinforcing (R) that can be described as follows:

1. R - loop: implementation of new technology - adaptive capacity of farmers to climate - development of climate field schools - non-structural approach: the implementation of new technology results in the increase in adaptive capacity of farmers to climate change and the development of climate field schools. All these efforts can support the non-structural approach.
2. B - loop: rehabilitation of irrigation networks - structural approach – adaptation to climate change: the rehabilitation of irrigation networks will support the structural approach and adaptation to climate change. The higher the adaptation to climate change will result in the decrease in the effort of the rehabilitation of irrigation networks.

c. Dimensional Consistency Test

Dimensional consistency tests is carried out to check the mathematical equations in the model have consistency in terms of dimensions. For example, the rendement of corn production can be explained as follows:

Rendement = RANDOM UNIFORM ({min} , {max} , {seed})
Rendement=RANDOM UNIFORM (0.85, 0.95 , 1)
Unit: dimensionless (Dmnl)

Rendement is a shrinking of corn production after the threshing process. It is a percentage of corn production obtained from the ratio of initial weight of corn to final weight after the threshing process. Rendement can be obtained by weighing the final weight with initial weight after threshing process. From observation, corn rendement of using hybrid seeds and composite seeds, the minimum = 85% and maximum = 95%. The rendement unit is in the form of a percentage, so that when it used as a model variable, the unit of rendement is defined as dimensionless (Dmnl) (Eberlein & Peterson, 1992).

d. Parameter Verification Test

The determination of parameter values of corn production model and adaptation to climate change comes from existing knowledge and numerical data gathered from interviews and observations in East Java Agriculture Service. Several model parameters, parameter values, and data sources are explained in Table 2.

Table 2. Model Parameter, Parameter Value, and References

Model Parameter	Parameter Value	References
Expansion rate	0.029 / Year	East Java Agriculture Service
Conversion rate	0.019 / Year	East Java Agriculture Service
Puso area in Tuban	2.8% - 4.0%	East Java Agriculture Service
Rendement	85% - 0.95%	East Java Agriculture Service

7

e. Extreme Condition Test: in this test, extreme values are applied to the selected parameters to analyze and compare the model behavior to the reference behavior of real system, under the extreme conditions. In the case of corn production model, the initial condition in one of model parameters is the rate of land expansion which is set at a value of 0.029. The test result for corn production of this initial condition can be seen in Figure 9. As we can see from Figure 9, corn production in Tuban has fluctuated between 379851 tons and 486985 tons.

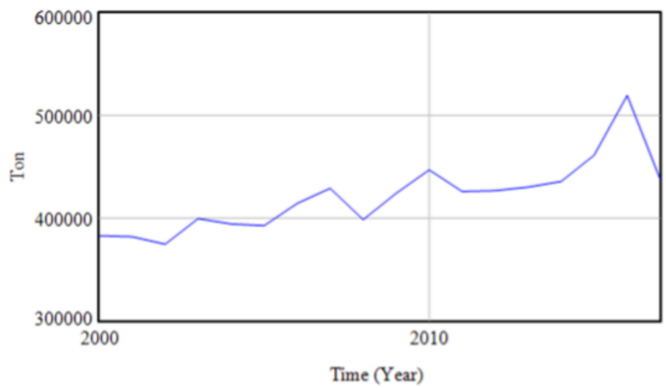

Figure 9. Corn Production in Tuban with Expansion Rate at 0.029

For testing in extreme conditions, the rate of expansion of the planting area is set at a value of 0.09, causing an extreme value of corn production in Tuban as shown in Figure 10. As we can see from Figure 10, in extreme condition corn production fluctuated between 379851 tons and 1319558 tons.

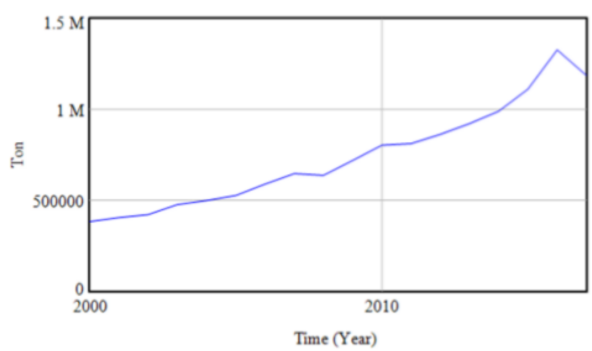

Figure 10 Corn Production in Tuban with Expansion Rate = 0.09

From the two graphs in Figure 9 and Figure 10, we can conclude that corn production in Tuban has increased in extreme condition, which means that the model behavior in line with the real system behavior. Therefore, we can conclude that the model passed the test of extreme conditions and the degree of validity has improved.

2.5.2 Behavior Validity Tests

Behavior validity test can be done by comparing the means and comparing the amplitude variations (Barlas, 1989). In this process, we need historical data during the time horizon starting from 2000 to 2017. We consider the time frame based on the data availability and the system behavior. Barlas stated that a model will be valid if the error rate is less than 5% and the error variance is less than 30% (Barlas, 1996). We validate some variables that have significant contribution to corn productivity and production such as harvested area, corn productivity, and corn production by utilizing the error rate and error variance formulations as defined in Eq. 13-18.

$$\text{Error Rate} = \frac{[\bar{S} - \bar{A}]}{\bar{A}} \quad (13)$$

$$\bar{S} = \frac{1}{N} * \sum_{i=1}^{N} Si \quad (14)$$

$$\bar{A} = \frac{1}{N} * \sum_{i=1}^{N} Ai \quad (15)$$

$$\text{Error Variance} = \frac{[Ss - Sa]}{Sa} \quad (16)$$

$$Ss = \sqrt{\frac{[S - \bar{S}]^2}{n}} \quad (17)$$

$$Sa = \sqrt{\frac{[A - \bar{A}]^2}{n}} \quad (18)$$

Where:

$\bar{S}$= the average rate of simulation

$\bar{A}$= the average rate of data

A= Data at time t

S = Simulation Result at time t

S_s= the standard deviation of simulation

S_a= the standard deviation of data

In this research, we obtain the data from the department of agriculture in East Java. Error rate of some variables of harvested area, productivity, and production are as follows:

Error rate of "harvested area" $= \frac{[\,92953 - 93171]}{93171} = 0.0023$

Error rate of "productivity" $= \frac{[\,50 - 51]}{51} = 0.0034$

Error rate of "production" $= \frac{[\,418729 - 421362\,]}{421362} = 0.0062$

Error variance of some variables of harvested area, productivity, and production are as follows:

Error variance of "harvested area" $= \frac{[\,4887 - 6157\,]}{6157} = 0.21$

Error variance of "productivity" $= \frac{[\,1.17 - 1.27\,]}{1.27} = 0.081$

Error variance of "production" = $\frac{[\ 29738\ -\ 34546]}{34546} = 0.139$

Based on the above calculation, all the error rates are less than 5% and error of variances are less than 30% which means that our model is valid.

2.6 Scenario Development

Scenario is a method for strategic planning to describe and analyze potential system developments in the future (Brose et al., 2013). It consists of several steps which include initial problem analysis and several projections of key factors to a final interpretation of the future condition. Scenario can be used to forecast demand and evaluate policy scenarios to understand the nonlinear dynamics of behavior under uncertain conditions and to increase the system performance (Suryani et al., 2010). Scenario can be done by adding some feedback loops, adding new parameters, changing the structure of the feedback loops, as well as change the model parameter (Suryani, 2011).

2.6.1 Land Expansion Scenario

In this research, the first scenario is developed by conducting land expansion to untapped areas such as forest land, dry land, or peatlands. Each area in East Java has different potentials in wetland expansion. In Tuban, the potential land expansion is about 25 ha/year. This annual land expansion will accumulate in "new corn land area in Tuban scenario 1" that will increase corn planting and harvested areas. The stock and flow diagram of harvested area as a result of land expansion can be seen in Figure 11.

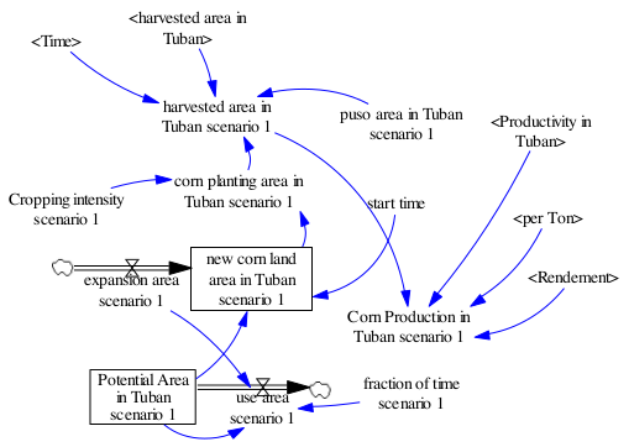

Figure 11. Scenario of harvested area in Tuban

Step function is utilized for one-time changed of 25 ha/year at time 2017. With this expansion, harvested area in Tuban scenario 1 will increase 25 ha/year. Model formulation for land expansion can be seen in Eq. 19-22. Land expansion scenario for other districts have the same structure, but different parameters due to the availability of potential land in each district. Corn production after land expansion depends on harvested area after land expansion, productivity, and rendement as seen in Eq. 23.

New Corn Land Area in Tuban scenario 1 =

STEP (IF THEN ELSE (Potential Area in Tuban scenario 1>0,

expansion area scenario 1 , 0) , start time) (19)

start time = 2017 (20)

Expansion Area Scenario 1 = 25 ha/year (21)

Harvested Area in Tuban Scenario 1 =

IF THEN ELSE(Time < 2018 , harvested area in Tuban ,

(harvested area in Tuban+corn planting area in Tuban scenario 1

-(corn planting area in Tuban scenario 1*puso area in Tuban scenario 1))) (22)

Corn Production in Tuban scenario 1 =

((harvested area in Tuban scenario 1*Productivity in Tuban)/10)

*Rendement*per Ton (23)

The stock and flow diagram for all total corn production in East Java can be seen in Figure 12. We also have developed stock and flow for fulfillment ratio to check the availability of corn supply as seen in Figure 13.

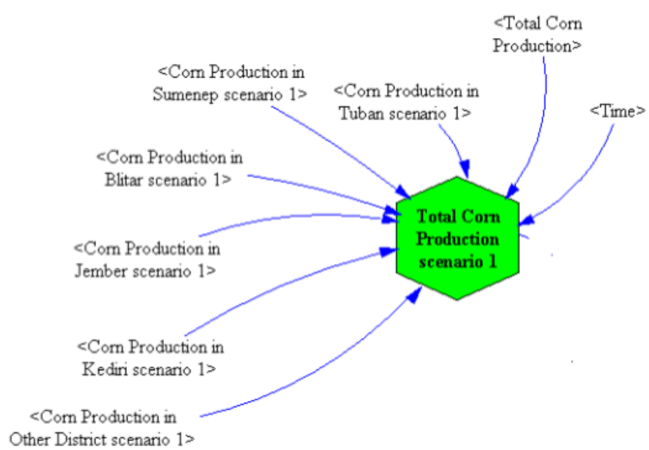

Figure 12. Stock and flow diagram for all districts in East Java

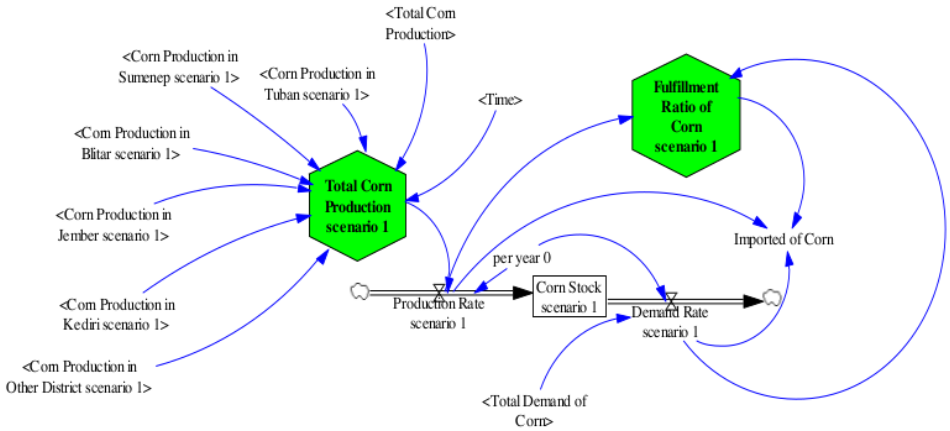

Figure 13. Stock and flow diagram of corn fulfillment ratio

Corn fulfillment ratio is the comparison between total corn production and demand in East Java as seen in Eq. 24.

Fulfillment Ratio scenario 1 = Production Rate scenario 1/Demand Rate scenario 1 (24)

2.6.2 Land Intensification Scenario

Land intensification scenario is developed to improve land productivity by modifying the structure of productivity model as seen in Figure 14. As we can see from Figure 14, we may increase the land productivity by conducting structural and non-structural approaches. Structural approach can be done through rehabilitation of watersheds and irrigation network. Meanwhile non-structural approach can be done through the implementation of new technology, strict rules of land conversion, dynamic cropping calendar, dissemination of climate information, and the development of climate field schools. Scenario formulation for land productivity improvement can be seen in Eq. 25-27.

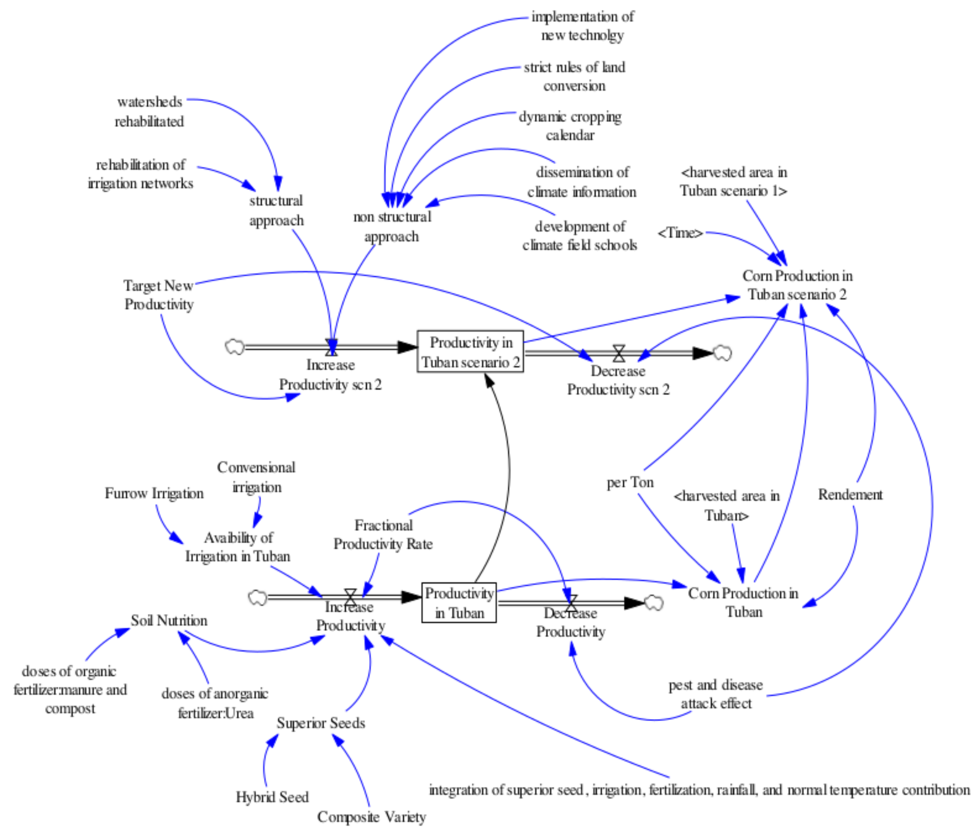

Figure 14. Land intensification scenario

Productivity scenario 2 =

Productivity Existing +

$$\int Increase\ Productivity\ scn\ 2 - Decrease\ Productivity\ scn\ 2 \quad (25)$$

Increase Productivity scn 2 =

((non structural approach+structural approach)*Target New Productivity (26)

Decrease Productivity scn 2 =

pest and disease attack effect*Target New Productivity (27)

2.6.3 Land Expansion and Intensification

This scenario is an integrated scenario between land expansion and intensification to check total corn production and fulfilment ratio in East Java. The stock and flow diagram of land expansion and intensification can be seen in Figure 15. Model formulation for total corn production and fulfilment ratio in East Java after land expansion and intensification can be seen in Eq. 28-29.

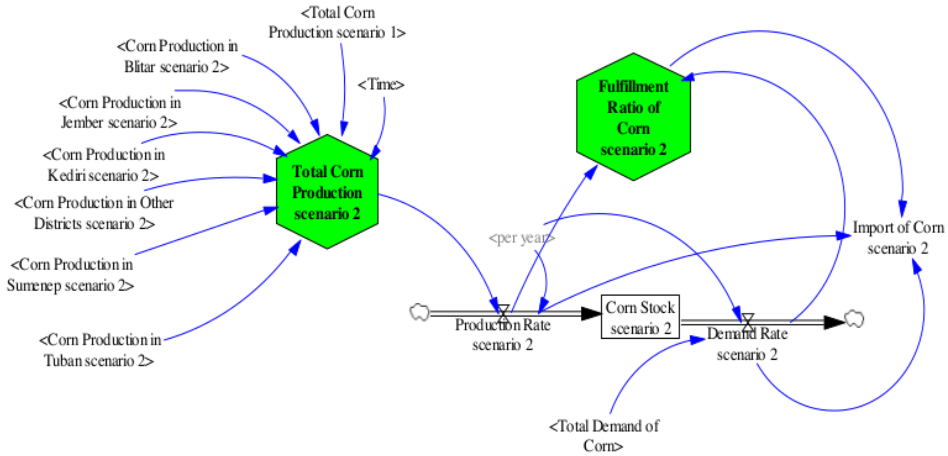

Figure 15. Stock and flow diagram of fulfillment ratio after land intensification and expansion

Total Corn Production = $\sum_{i=1}^{6} Corn\ Production\ in\ Each\ Districts(i)$ (28)

Fulfillment Ratio After Land Expansion and Intensification =

Production Rate scenario 2/Demand Rate scenario 2 (29)

3. RESULTS AND ANALYSIS

This section demonstrates results and analysis of harvested areas, corn productivity and production, as well as scenarios results to improve corn productivity and production.

3.1. Harvested Areas

Harvested area covers several corn farming centers in East Java area covering Tuban, Jember, Kediri, Blitar, Sumenep, and several other districts in East Java. Each area has different characteristics that affect the corn harvest area. Several factors affecting corn harvest area in East Java include land area for corn planting area, cropping intensity, and puso area. Corn land area is determined by expansion and conversion areas as shown in Figure 16-18. Expansion areas within the time frame od 2000-2017 grew at an average annual growth of 12.78 ha/year, while conversion area also grew at an average growth rate of 8.37 ha / year per year.

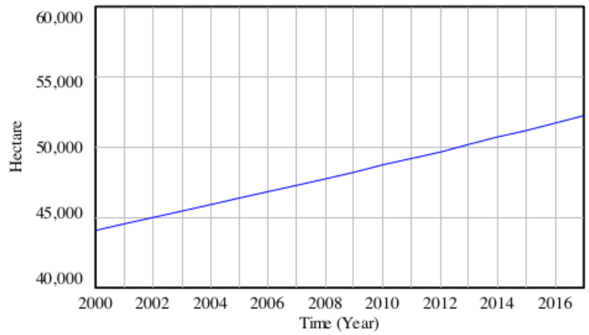

Figure 16. Corn land area in Tuban

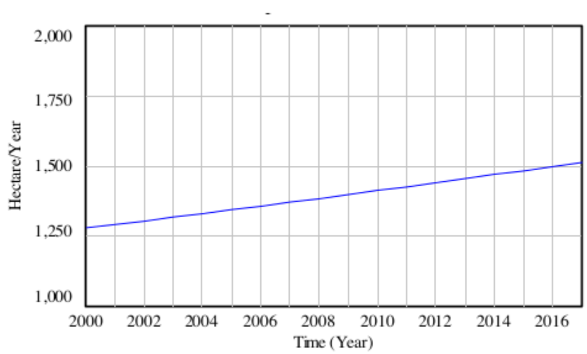

Figure 17. Expansion area in Tuban

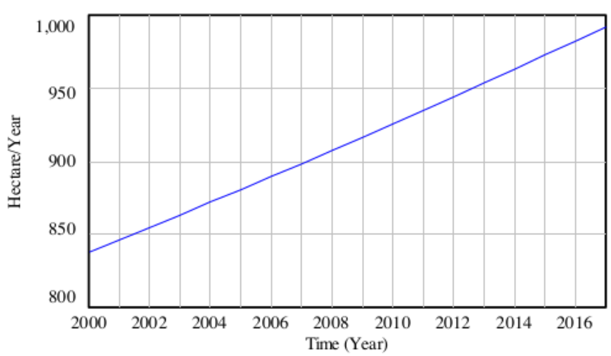

Figure 18. Conversion area in Tuban

From the historical data, it is found that puso area was between 2.8% and 4% of the corn planting area. Corn planting area is determined by corn land area and cropping intensity. Harvested area is determined by cropping intensity and puso as seen in Figure 19. The harvested area in Tuban in the year 2000 was about 85.225 ha and 101.093 ha in 2017. The average growth rate of land expansion was around 2.9% and land conversion for infrastructure development was around 1.9% as shown in Figure 17-18. Harvested areas for other areas throughout East Java can be seen in Table 3. Meanwhile, total harvested areas for all areas in East Java can be seen in Figure 20.

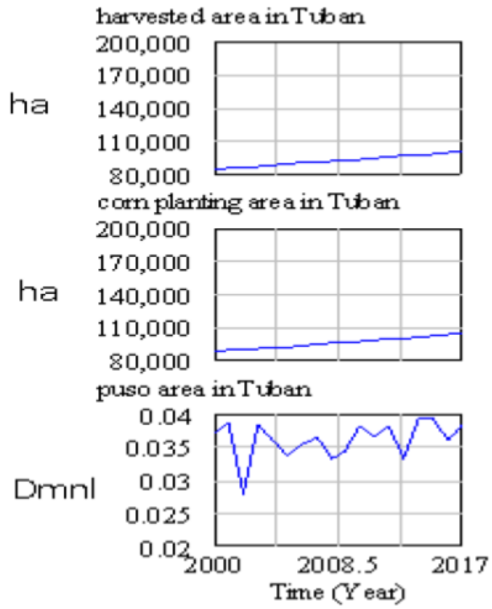

Figure 19. Harvested area in Tuban

Figure 20. Total harvested areas in East Java

Table 3. Harvested area in several regions in East Java

Time	Harvested Area (ha)					
	Tuban	Jember	Kediri	Blitar	Sumenep	Other Regions
2000	85225	39434	44422	35072	149652	881351
2001	85888	40484	44542	35831	149095	881628
2002	86688	41213	45260	36647	148807	887628
2003	88142	42579	45552	37441	148724	867875
2004	88320	43770	46179	38262	148104	874025
2005	89099	44884	46042	39106	147462	860260
2006	90761	46201	46633	39950	147171	855431
2007	91613	47185	47168	40841	146904	860999
2008	91937	48728	47299	41718	146737	847219
2009	93384	49745	48129	42652	146227	836446
2010	93582	51180	48720	43617	145850	843169
2011	95252	52534	48625	44552	145240	833566
2012	95766	54050	49423	45543	144829	831277
2013	96704	55468	49855	46553	144193	818304
2014	98429	56791	50334	47553	144416	812923
2015	98944	58433	50913	48609	143752	817107
2016	99501	60072	50813	49654	143065	802970
2017	101093	62048	51601	50745	143405	803144

3.2 Corn Productivity and Production

The productivity of corn farming is the yield obtained in one hectare of harvested area. Simulation results of corn productivity is demonstrated in Figure 21. As we can see from Figure 21, corn productivity in Tuban Area (one of corn center areas in East Java) in 2000-2013 was around 50 quintals/ha, then decreased to 48.56 quintals/ha in 2014, rising to 51 quintals/ha by 2015, and became 54.58 quintals/ha in 2016, while declining again in 2017 to be around 50.71 quintals/ha. The rise of productivity is caused by various factors such as irrigation, soil nutrition which is the effect of organic and inorganic fertilizer, superior seeds, as well as pest and disease. The decrease in productivity in 2014 was due to increased pest and disease as a result of climate change during the year. While productivity improvement in 2016 is caused by various factors that support productivity such as the availability of irrigation, balanced fertilization, and climatic conditions.

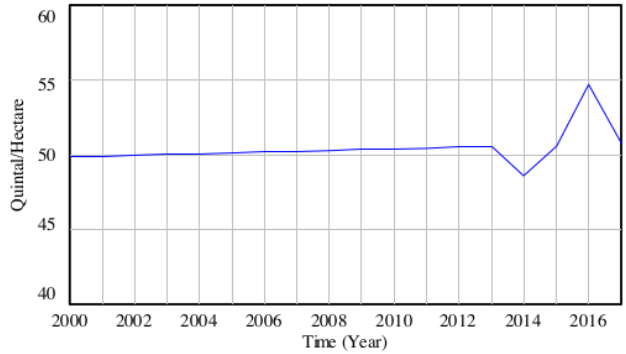

Figure 21. Corn productivity in Tuban

Corn production fluctuates from year to year, due to harvested area, productivity, and rendement as shown in Figure 22-24. Corn production in 2016 has the highest value of 513129 tons with harvested area of 99688.59 ha, productivity of 5.47 tons/ha, and rendement that reached around 0.94. Furthermore, corn production, harvested area, productivity, and rendement within 2000-2017 in Tuban area can be seen in Table 4. For other districts, corn productivity and production can be seen in Figure 25 – 34. Total corn production in East Java within 2000-2017 can be seen in Figure 35. As we can see from Figure 35, total corn production in East Java from 2000-2016 tend to decline, but an increase in 2017 as the impact of land productivity, harvested area, and rendement.

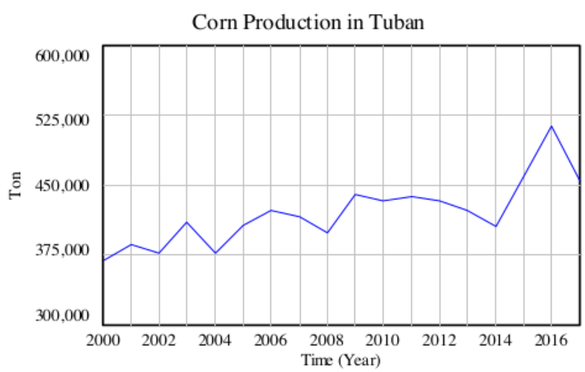

Figure 22. Corn production in Tuban

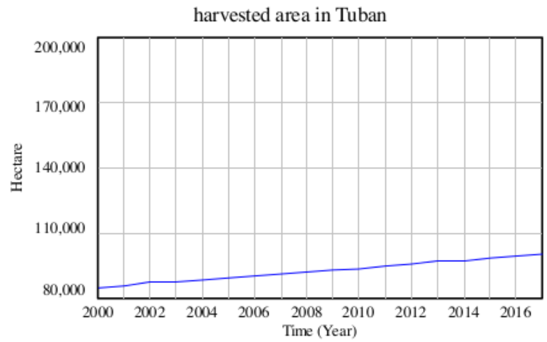

Figure 23. Harvested Area in Tuban

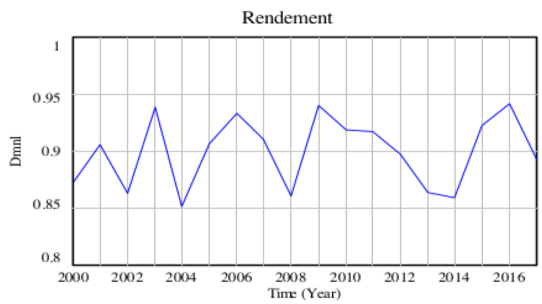

Figure 24. Corn rendement in Tuban

Table 1. Corn Production, Harvested Area, Productivity, and Rendement in Tuban

Time (Year)	Corn Production in Tuban (Ton)	Harvested area in Tuban (ha)	Productivity in Tuban (Ton)	Rendement
2000	369530.03	84894.44	4.99	0.87
2001	386776.88	85608.94	4.99	0.91
2002	376765.75	87439.02	5.00	0.86
2003	410165.78	87382.08	5.00	0.94
2004	377077.38	88456.71	5.01	0.85
2005	406633.63	89559.62	5.01	0.91
2006	422500.88	90292.77	5.02	0.93
2007	416231.97	91109.77	5.02	0.91
2008	399115.63	92311.58	5.03	0.86
2009	440644.88	93142.06	5.03	0.94
2010	433537.31	93706.42	5.04	0.92
2011	438187.97	94773.28	5.04	0.92
2012	432885.69	95580.88	5.05	0.90
2013	423157.13	97027.14	5.05	0.86
2014	406286.81	97392.89	4.86	0.86
2015	459272.84	98377.35	5.06	0.92
2016	513129.00	99688.59	5.47	0.94
2017	454366.63	100431.26	5.07	0.89

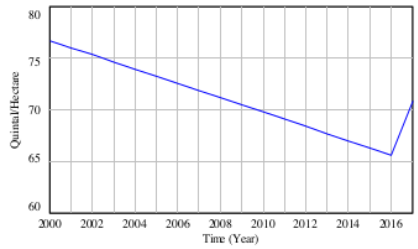

Figure 25. Corn productivity in Jember

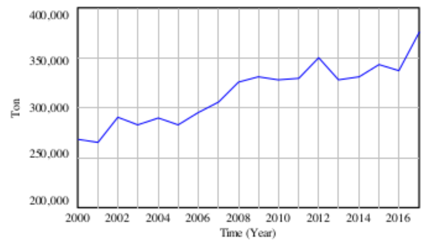

Figure 26. Corn production in Jember

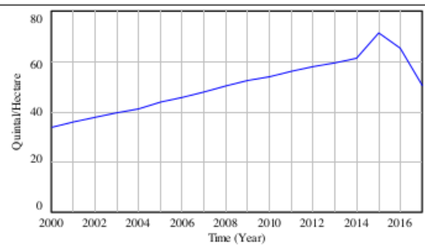

Figure 27. Corn productivity in Kediri

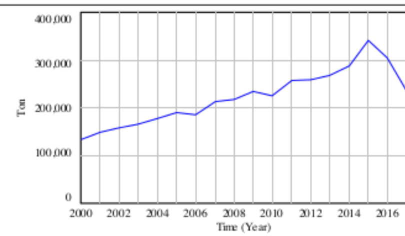

Figure 28. Corn production in Kediri

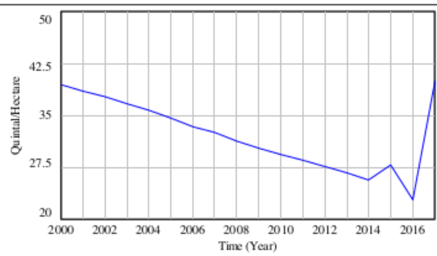

Figure 29. Corn productivity in Sumenep

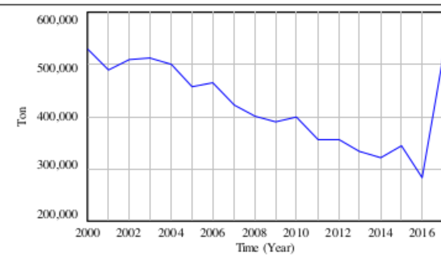

Figure 30. Corn production in Sumenep

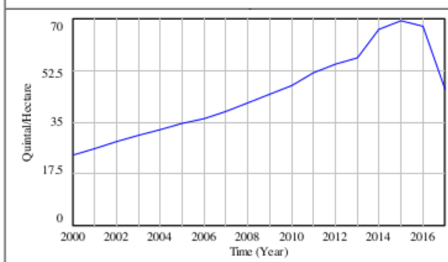

Figure 31. Corn productivity in Blitar

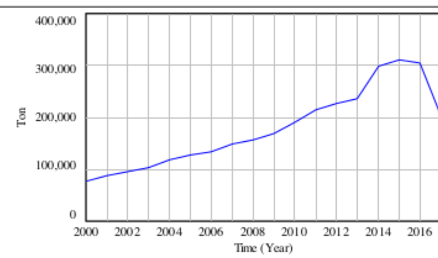

Figure 32. Corn production in Blitar

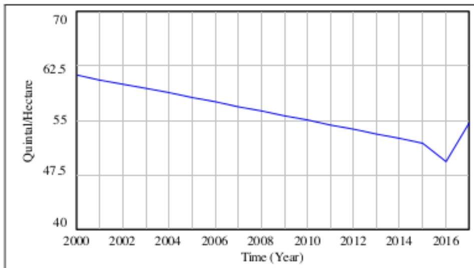

Figure 33. Corn productivity in other districts

Figure 34. Corn production in other districts

Figure 35. Total corn production in East Java

3.3 Scenarios Results and Analysis

This section demonstrates scenario results of land expansion and land intensification to analyze the impacts to corn production and productivity. Once the model is valid, we can develop several scenarios to increase the harvested area, production, and land productivity. By referring to the scenario development, we might use the scenario as a method for strategic planning to describe and analyze potential system developments in the future. In this research, we set the time frame of the scenario up to 2030 based on consideration that during that time we can develop various efforts to increase the area of harvests, production, and land productivity gradually to meet the future demand.

3.3.1. Land Expansion

Land expansion scenario is conducted to increase harvested area, corn productivity, and corn production. Total harvested area and corn production after land expansion in east Java can be seen in Figure 36-37. As we can see from Figure 36, total harvested area in East Java would increase with the average growth of around 0.6% per

year. With this growth, it is estimated that total harvested area in East Java would be around 1.32 M ha in 2030. Total corn production is estimated would achieve 7.2 M tons in 2030 as the impact of land expansion, productivity, and rendement as seen in Figure 37.

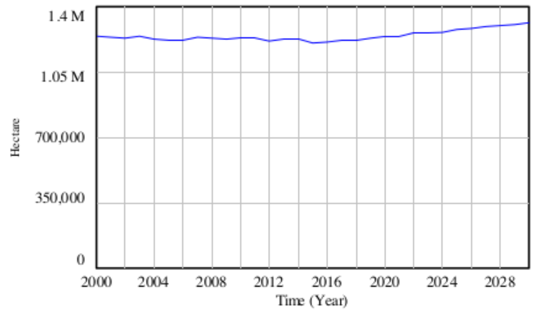

Figure 36. Total harvested area after land expansion

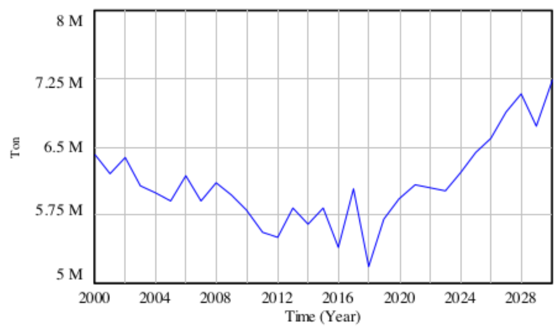

Figure 2. Total corn production after land expansion

3.3.2. Land Intensification

Land intensification scenario is conducted to increase land productivity. Land productivity in several districts in East Java before and after land intensification can be seen in Figure 38 - 43. As we can see from Figure 38-43, the average land productivity after land expansion would be around 73.08 quintals/ha as **the impact of the implementation of structural and non-structural approaches**.

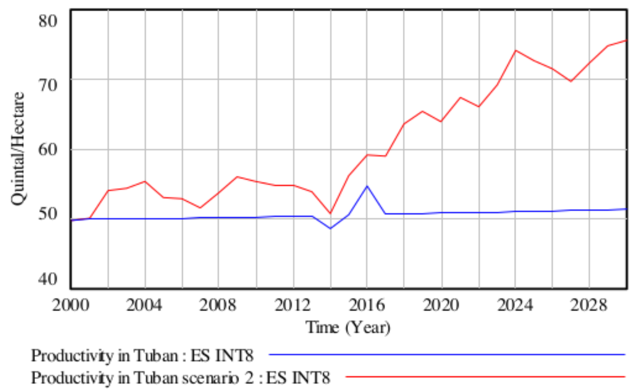

Figure 38. Land productivity in Tuban before and after land intensification

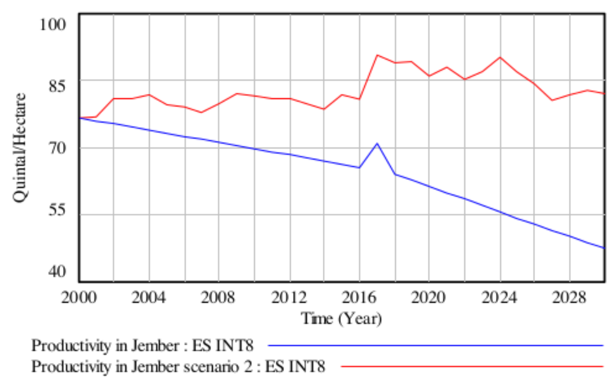

Figure 39. Land productivity in Jember before and after land intensification

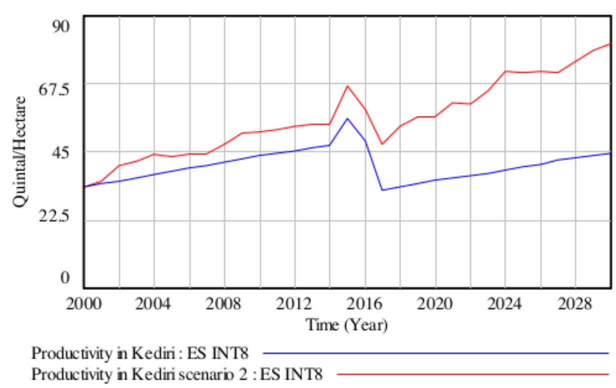

Figure 40. Land productivity in Kediri before and after land intensification

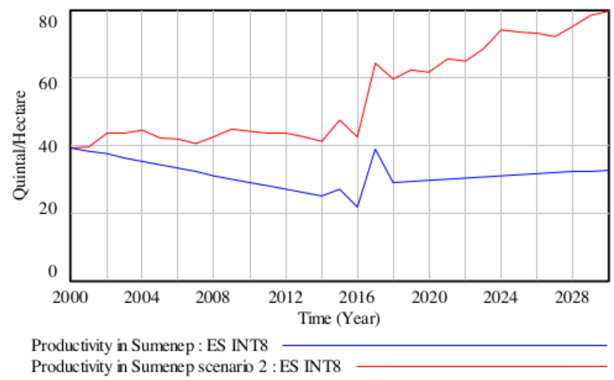

Figure 41. Land productivity in Sumenep before and after land intensification

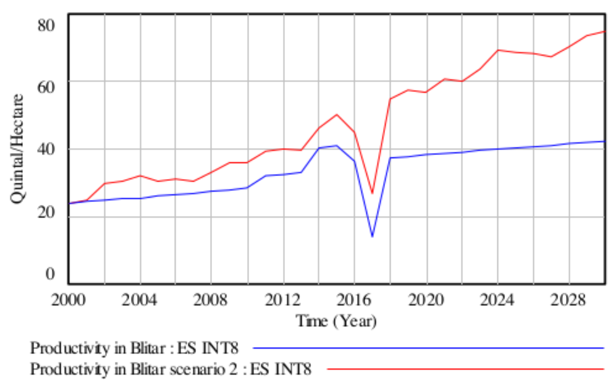

Figure 42. Land productivity in Blitar before and after land intensification

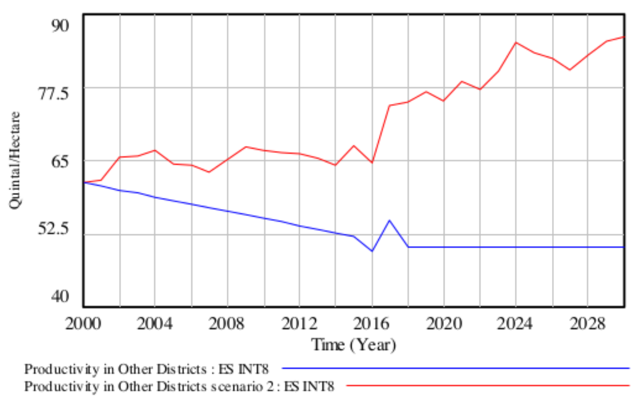

Figure 43. Land productivity in other districts before and after land intensification

3.3.3. Land Expansion and Intensification

This scenario is an integrated scenario between land expansion and intensification to check the total corn production and fulfilment ratio in East Java. Total corn production and fulfilment ratio in East Java after land expansion and intensification can be seen in Figure 44. As we can see from Figure 44, total corn production in East Java after land expansion and intensification would achieve 15 M tons in 2030. Meanwhile fulfilment ratio in East Java would achieve 1.68, which means that East Java can fulfill its regional future demand as seen in Figure 45.

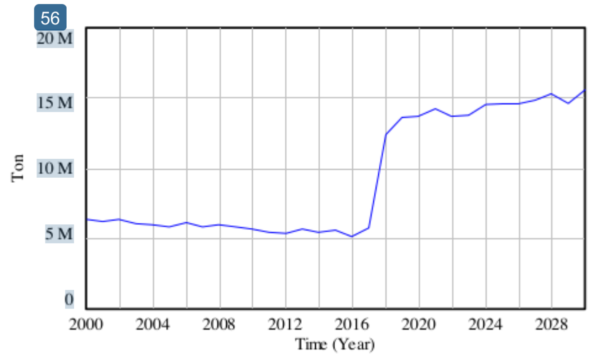

Figure 44. Total corn production after land expansion and intensification

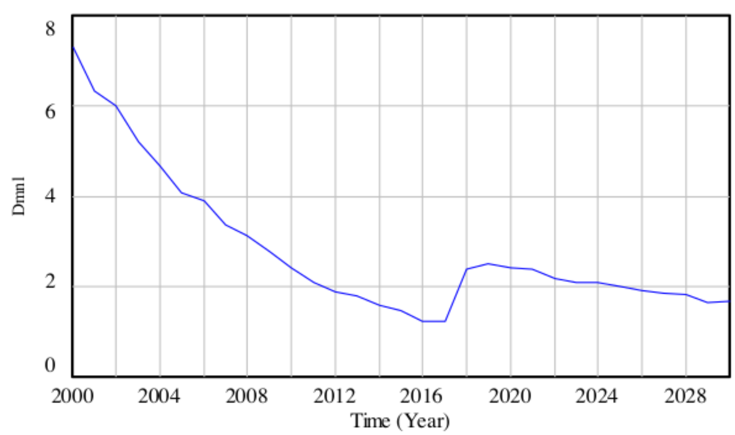

Figure 3. Corn fulfillment ratio after land expansion and intensification

4. CONCLUSION AND FURTHER RESEARCH

Based on the existing condition, corn production fluctuates from year to year, due to harvested area, productivity, and rendement. Total corn production in East Java from 2000-2016 tend to decline, but an increase in 2017 as the impact of land productivity, harvested area, and rendement. Corn production can be increased through land intensification and expansion. In this research, we have developed some scenarios to conduct land intensification and expansion by using structure and parameters scenarios. Scenario can be done by adding some feedback loops, adding new parameters, changing the structure of the feedback loops, as well as change the model parameter. In this research, we set the time frame of scenario up to 2030 based on consideration during the time frame, we can develop various efforts to increase the area of harvests, production, and land productivity gradually to meet the future demand.

Corn production after land expansion depends on **the** harvested area after land expansion, productivity, and rendement. Several factors affecting corn harvested area include **land area for corn planting**, cropping intensity, and puso area. Results show that total harvested area after land expansion would increase with the average growth of around 0.6% per year. With this growth, it is estimated that total harvested area would be around 1.32 M ha in 2030. Total corn production is estimated would achieve 7.2 M tons in 2030 as the impact of land expansion, productivity, and rendement. Corn productivity after land intensification would be around 73.08 quintals/ha as the impact of structural and non-structural approaches implementation. Total corn production in East Java after land expansion and intensification would achieve 15 M tons in 2030. Meanwhile fulfilment ratio in East Java would achieve 1.68, which means that East Java can fulfill its regional future demand.

For further research, we may enhance the model scope into corn supply chain management to increase the value chain of all stakeholders. We might consider supply, demand, distribution, customers, as well as the processed corn products.

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