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Analysis of soybean production to achieve soybean self-sufficiency using system dynamics approach

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ABSTRACT: Soybean is widely used as raw material of various types of processed foods. The still remaining problem today is the soybean's demand that is not balance when it's compared to the farmer's soybean production. This could affect soybean shortage. If the need of soybean in East Java Province can be fulfilled, then East Java Province can be said to have a surplus and self-sufficiency of soybean. The decline in soybean production was influenced by handled and unhandled factors. The contribution of this paper is modeling soybean production and scenario. Both were used to increase soybean production, so that it can achieve self-sufficiency by considering the variables that influence in soybean production. This research use system dynamic approach because it can be used like a tool to provide information and feed back to the system and offer a solution from developed scenarios.

Keywords: Soybean, Production Analysis, Self-Sufficiency, Demand, System Dynamics

1. INTRODUCTION

The agricultural sector has an important contribution to national development. Soybean is one of food crops commodities, all of the food crops are surplus, except for soybean. The East Java Province has an excellent products are Rice and Corn (see Figure 1), in other side, Soybeans and other food crop commodities, which potentially in terms of economy and employment. The Soybeans commodities are one of example from many commodities potential in east java. Until now, The Government need's import to fulfillment of soybean commodities, soybean is a raw material in the manufacture of "tempe", tofu and soy sauce, etc.
The harvest area of Soybean commodities slowly decline from 2000 until now, with an average decrease of 5% and a 3% increase (see Figure 2), the highest decrease occurred in 2006 to 2007 amounted to 19% (1). It's caused by pest, plant diseases and rainfall (2), and infrastructure development, resident building and industry areas (3). Conversion of harvest area can be affect productivity (4).
The Soybean demand is still not balanced compared to the production of soybean farmers, if requirement of soybean can be fulfilled, then East Java Province can be said to have a surplus and self-sufficiency. The contribution of this paper is modeling soybean production and scenario to increase soybean production. First, expansion of land area and the second, seed treatment, both were used to increasing soybean production, so that it can achieve self-sufficiency by considering the variables that influence in soybean production. This research use system dynamic approach because it can be used like a tool to provide information and feed back to the system and offer a solution from developed scenarios.
To be able to answer the question then in this research need to do stages in solving the above problem, first, creating a causal loop, secondly, creating a base model, and third, developing the model by

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incorporating the scenario of adding new planting area with dynamic system simulation approach. A system dynamics approach is used in this research because it can be used as a tool that can provide information in relation to the decision making process (5), a complex dynamic system approach requires formal models and simulation methods to test, improve and design a new policy (6).

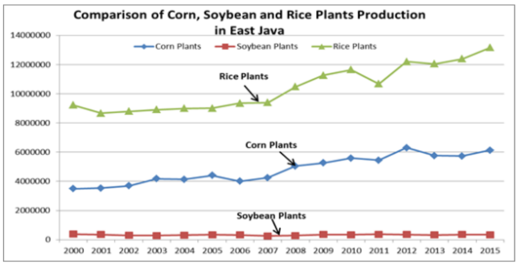

Fig.1 Comparison of Corn, Soybean and Rice Plants Production in East Java. (1)

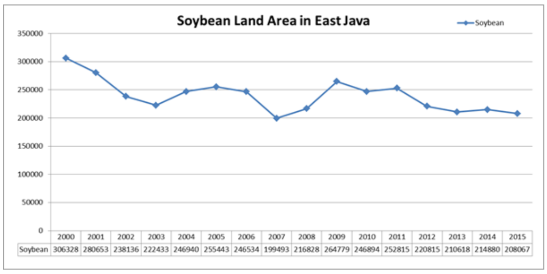

Fig.2 Harvest Area of Soybean in East Java. (1)

2. METHODOLOGY

In this section will be discussed about modelling, system dynamics, step by step development using system dynamics approach and validation.

2.1 Modelling

Modelling is to use a certain formal language with the help of software to the imitate system in real life the focus which of attention and subject matter in the study (7)

2.2 System Dynamics

The dynamic system interprets real systems into computer simulation models that allow one to see structure and policies (8). Stocks and flows are a main component in system dynamics approach, Stocks represents some of the information or entity in the system, Flows define the rate of change to stocks-add or subtract-more from the type of information or entity to the stocks (9)

2.3 Step by Step System Dynamics Approach

In this research using five stages in developing a dynamic system model from Sterman(2000) (6) i.e: step 1: problem articulation, step 2: dynamic hypothesis, step 3: formulation, step 4: testing, step 5: policy formulation and evaluation. The five stages are described in the flowchart as follows

2.4 Validation

The results from the simulation will be validated to ensure that the model created can really describe the real system condition, validation system using two way of testing that is model validation with statistical test of mean comparison or validation model with comparison test of amplitude variation or % error variance (10):

a. Mean Comparison

$$\boldsymbol{E1} = \frac{|\bar{S}-\bar{A}|}{\bar{A}} \qquad (1)$$

Where :

$\bar{S}$ = **average of data simulasi**

$\bar{A}$ = **average of real data**

Model valid if $\boldsymbol{E1} \leq \mathbf{5}\ \%$

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% error variance

$$E2 = \frac{|Ss - Sa|}{Sa} \quad (2)$$

Where :
Ss = Standart Deviation Model
Sa = Standart Deviation Data
Model valid if $E2 \leq 30$ %
The model are considered valid when $E1 \leq 5$ % and $E2 \leq 30$ %.

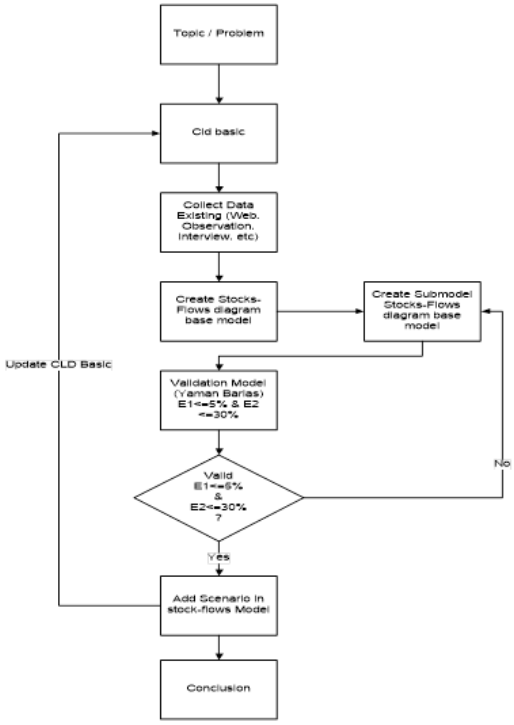

Fig.3 Methodology using system dynamics (7),

3. RESULTS

In this section will be discussed about result causal loop/causatic diagram, stock-flow diagram and stock-flow diagram with scenario, validation model.

3.1 Causal Loop Diagram

Causal loops are used as translating each variable that affects production, productivity and harvested area on soybean commodities, in the causal loop, the variable described must have a relationship or affect each other to that variable and have feedback on the existing system (11). Soybean production is influenced by productivity and harvest area, the causal loop diagram is used to perform the simulation using systems dynamic approach by the visible components (12).

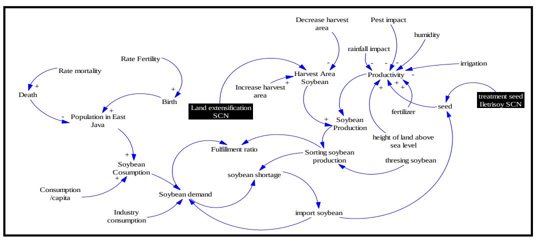

Fig.4 Causal loop diagram

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3.2 Stock Flow Diagram Base Model

Base model is the model as used for the initial model to do validation of model. The variables of production are influenced by land area and productivity, whereas productivity and land area have an increase and decrease caused by certain factors. Figure 5 are a stock flow diagram of production, productivity and harvest area soybean.

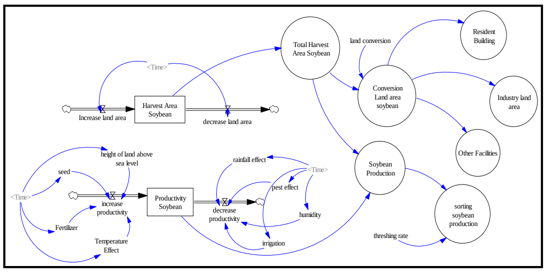

Fig.5 Stock flow diagram of production, productivity and harvest area soybean

In figure 6, displayed graph about harvest area, productivity and production soybean. Overall, it can be said that the harvest area decline while the productivity increase, in another side, there is a relationship between harvest area with production, harvested area increase or decrease then the production follows the down. Productivity land in East Java is stable in well condition, but the harvest area conversion, make land area reduce.

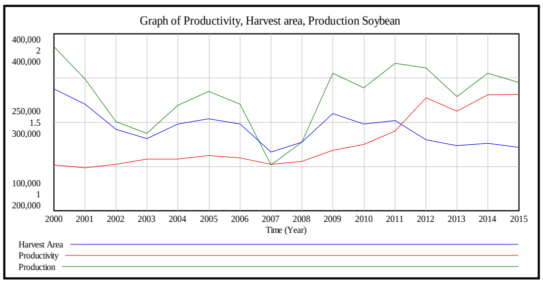

Fig.6 Graph of Productivity, Harvest Area and Production Soybean

3.3 Validation Model

Modelling validation in this paper using 2 methods, first, the model validation with statistical mean comparison and using error variance (10).

Table 1 Validation production model

Year	Production data	Simulation data
2000	385212	385361
2001	349188	349062
2002	300184	300403
2003	287205	287252
2004	318929	319147
2005	335106	335236
2006	320205	320298

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2007	252027	251940
2008	277281	277302
2009	355260	355264
2010	339491	339248
2011	366999	366837
2012	361986	361659
2013	329461	329165
2014	355464	355151
2015	344998	344618
Mean	351933	351863
Standart Deviasi	35809.1	35750.11

E1 = (|(351933-351863)| : 351863) = 0.000199
E2 = (|(35809.1-35750.11)| : 35750.11) = 0.00165

$\boldsymbol{E1} \leq \mathbf{5}\,\%$ → 0.000199 x 100% = 0.0199
$\boldsymbol{E2} \leq \mathbf{30}\,\%$ → 0.00165 x 100% = 0.165
This model valid because $\boldsymbol{E1} \leq \mathbf{5}\,\%$ and $\boldsymbol{E2} \leq \mathbf{30}\,\%$.

3.4 Stock Flow with Scenario

The scenario using in this research are expansion of land area and seed treatment. The Ministry of Agriculture will add 500,000 hectares to expansion of planting area (Perluasan Area Tanam(PAT)) (13), and the second, using seed treatment (14). Based on the description, the sub-model on expansion of planting area (PAT) and seed treatment then added in model for period 2016 to 2025 (Figure 7). The results from model development using scenarios of land expansion and seed treatment scenarios are increasing productivity and production soybean.

Production soybean at 2015 is 344,618 Ton, after using scenarios at 2016 is 1,205,242 Ton, productivity at 2016 increase amount 1.7 Ton/ha, and harvest area subsequent to PAT is 707,991 hectares(ha)(**appendix A** of the scenario summary and **appendix B** on data comparison).

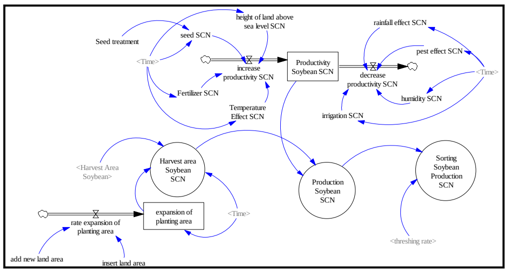

Fig.7 Modelling Scenario With Expansion Of Planting Area And Seed Treatment

4. CONCLUSION

Based on the results of the analysis and development of the model it can be concluded:

a. In the case of model development using system dynamic approach, it needs deep understanding and information about current conditions, based on the validation in development of model then the model in this research is valid.
b. The addition in expansion of land area and seed treatment in the scenario shows a decrease in soybean shortage, but this scenario can increase the production, harvest area and productivity soybean crops.
c. In this research successfully develop productivity model with adding variable irrigation,

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humidity, seed, rainfall, fertilizer, pest, temperature and height of land above sea level. Production variable influenced by productivity and harvest area. Whereas, ratio fulfilment indicates a correlation between production and harvested area.

The suggestion for further research are model of market price stability based on demand and supply with consider inflation and deflation, and models of logistics using system dynamics approach.

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Appendix A

Resume Scenario

Scenario	Explanation	Result
Scenario: expansion of land area and seed treatment	**Before using scenario**	1. Harvest area at 2015 is 207,852 Ha 2. Production at 2015 reach is 344,168 Ton 3. Soybean shortage reach is minus 426,765 Ton
	After using scenario	1. The harvest area after apply PAT scenario at 2016 (add 500,000 Ha) reach 707, 991 Ha and then, in the final period of the simulation (2025) is 709,248 Ha 2. Production soybean at 2016 is 1,206,243 Ton and in the final period of the simulation (2025) is 1,531,111 Ton. 3. Production Soybean shortage reach is minus 377,234 Ton

Appendix B

Data comparison of harvest area and production before and after scenario applied

Tahun	Harvest Area (Ha)	Harvest Area Scenario PAT (Ha)	Produksi Kedelai (Ton)	Produksi Kedelai Skenario PAT (Ton)	Kekurangan (-) atau Surplus (+)
2000	306,328		385,361		-374,928
2001	280,596		349,062		-380,568
2002	238,226		300,403		-387,131
2003	222,503		287,252		-391,170
2004	247,018		319,147		-391,990
2005	255,516		335,236		-393,981
2006	246,573		320,298		-398,240
2007	199,477		251,940		-406,380
2008	216,812		277,302		-407,808
2009	264,727		355,264		-405,484
2010	246,726		339,248		-409,963
2011	252,643		366,837		-411,339
2012	220,658		361,659		-415,111
2013	210,464		329,165		-420,888
2014	214,723		355,151		-422,492
2015	207,852		344,618		-426,765
2016		707,991		1,205,243	-368,268
2017		708,130		1,237,720	-369,423
2018		708,270		1,271,072	-370,543
2019		708,409		1,305,324	-371,624
2020		708,549		1,340,498	-372,667
2021		708,689		1,376,620	-373,669
2022		708,828		1,413,716	-374,628
2023		708,968		1,451,812	-375,543
2024		709,108		1,490,934	-376,412
2025		709,248		1,531,111	-377,234