Analysis of sugar import policy effects on sugar cane farmer’s income in East Java: A system dynamic approach

A F Fudhla1,2, W Rachmawati1,3, and D Retnowati1,4

1Industrial Engineering, Universitas Maarif Hasyim Latif, Raya Ngelom Megare Taman Sidoarjo 61257

E-mail: 1fatih_fudhla@dosen.umaha.ac.id, 2windirachmawati.97@gmail.com, 3dini_retnowati@dosen.umaha.ac.id

Abstract. Besides rice, sugar becomes a national strategic agricultural commodity in Indonesia. Until 2019, since local sugar production has not been able to meet national needs, import is required. However, the uncontrolled entry of imported sugars could hit the presence of the local sugar. This can smite particularly the traditional sugar cane farmers who are the backbone of national sugar production. Based on the observation in East Java as a province with the largest sugar production in Indonesia, in recent years, when they are depressed with the increase of living and farming costs, the entry of imported sugar in large volumes will make their conditions worse. This study develops a system dynamics model that can evaluate the impact of sugar import policies on the fluctuations in the welfare of traditional sugar cane farmers in East Java. After the validation process, the result of simulation shows that if there are imported sugars in volume 10% of local productions, sugar cane farmers’ incomes decrease 38% on average per year. When imported sugars reach 60% of local production, sugar cane farmers’ annual income dropped drastically tends to go bankrupt. When there are no imported sugars, the income crept up an average of 4.35% per year. The Model could be used by policy makers as an early warning mechanism on this issue.

1. Introduction
Sugar is one of the agriculture strategic commodities in Indonesia [1]. National sugar consumption in 2018 reaches 5.5 million tons which domestic production could fulfill only 38% [2]. As the largest sugar-producing province in Indonesia [3], East Java has an important role in national sugar needs fulfillment [4]. Its sugarcane farmers have a key role in the supply of sugar raw material [5]. Nevertheless, since 2012 sugar production has decreased [2] and affected the depression in sugar businesses, especially sugarcane farmers. During the sugarcane planting, sugar price has increased, but when harvesting it has decreased. it gets worse when imported sugar came into East Java. Imported sugar is a national policy intended to meet the lack of supply to national sugar demand [2]. However, the entry of refined sugar/imported sugar into East Java which has a surplus in sugar production could cause huge problems [3]. Big traders or broker were the sides who benefit the most, sugar cane farmers welfare were the worst, so an analytical study is needed to relieve this problem.

Furthermore, the sugarcane was not a simple system, many complex interactions between system components [6]. One analytical method that can accommodate them is system dynamic approach [7]. This study developed an instrument of system dynamics modeling that could evaluate how traditional sugar cane farmers’ welfare fluctuation in East java affected by sugar import policies.

2. System Dynamics Modelling
System dynamics is a simulation methodology to describe and analyze the complex feedback system that the behaviors are changing over time [8]. According to Feofilovs et.al [9], System dynamics is a simulation model that used to describe the complexity of system behavior which includes social aspects by using causal loops and stock and flow in its interactions.
Simulation dynamic system modelling was initially developed at the United State by JW Forrester in 1956, which is used to analyse complex behaviour in social science, especially in management science. While according to Forrester [10], system dynamics is a simulation methodology used to analyse complex systems that change from time to time, especially in management science and modern control theory using computer simulations.

In the modelling, the initial step is “fully understanding” the real system behaviour, then identifying variables and relations among them using the Causal Loop Diagram (CLD). The feedback relationships generate the loops that will make the system behave simultaneously and dynamically like a real system [11] [12]. The main concept of system dynamic theory is stock and flow. Stock is an element that can change and can describe the process of storing materials. Stock can change due to the influence of flow. While flow shows the pattern of changes in stock and adds or reduces some entities or information. In the model, flow is addressed as a variable that can affect a stock level [12] [13].

Model validation is performed to determine the accuracy of a model based on mathematical equations. To show the real problem, the model has to be simulated to obtain outputs based on system behaviour [14]. If model behaviour similar to the real system, then the model is valid [15].

2.1. Previous Research (System Dynamic in Agriculture)
System dynamic approaches in various fields of agriculture have been carried out in previous studies, including such as; research on production and soybean demand [16], supply chain perspective of soybean sufficiency [17], research that discusses the hydrological process in plantations [18], studies that discuss the welfare of farmers and developing scenarios how to reduce poverty of farmers in Central America [19], and in New Zealand [20]. While previous system dynamic research related to sugarcane farming or sugar systems included; research that discusses the exploration of sugarcane yields that affect the production process and ethanol consumption in Brazil [21], research for enhance availability of sugar in East Java [1], and research examining sugarcane logging in the Bondowoso Indonesia [22]. No research discusses the welfare of sugarcane farmers in System Dynamics before.

3. Result and Discussion
3.1. Research Object Description
East Java is the largest sugar-producing province in Indonesia. In 2018, it produced 1.04 million tons of sugar, which up to 450 thousand tons were absorbed by local needs, and the remaining were absorbed by national needs. Based on data from Indonesia’s Central Bureau of Statistics/ “Badan Pusat Statistik” (BPS), East Java has the largest sugarcane area up to two hundred thousand hectares. In this province stand 33 plants of sugar cane refineries, the largest number in Indonesia, owned by state and private companies. Based on data from BPS 98% of sugarcane land in East Java is owned and managed by farmers, others by state and private companies. These show that most sugar raw material supply is obtained from the sugar farmers' harvest. There are two large groups of farmers, namely landowners/farmers and farmworkers. In this study, these two groups' income will be highlighted as a very vulnerable welfare class when there are imported sugars got into East Java Province.

3.2. Sugarcane Farmers Welfare System Dynamic Model
This research begins with the identification of the variables involved in the income of sugar cane farmers and farmworkers, and then it will be outlined in the Causal Loop Diagram (CLD). By using Vensim (Ventana Simulation), the relationship between variables in the income system of Sugar Cane Farmers in East Java is shown in Figure 1.
education costs, and operational costs for farmers. Operational costs are formed from processing costs, expenditure per period. Expenditure is derived from the income of the farmer, i.e. the total amount of income that has been reduced by the total amount of expenditure per period. Imported sugars affect price through the rate of sugar produced from sugarcane and rate of burned sugarcane. The rate of burned sugarcane is affected by the total monthly harvesting act of each farmer. Figure 1 shows the interaction among variables. Positive arrows indicate a positive relationship and negative arrows indicate a negative relationship. The different colours highlight two central variables, “Farmer Net income (saving)” and “farmworkers net income (saving)”. The Farmer is influenced negatively by farmers expend rate and positively by income rates. It's means that “farmers net income” will decrease when the expend rise and increase when the income ascend. Imported sugars affect price through the stock/storage. “Sugar consumption rate” will decrease when the price increases.

Figure 2 is a Stock and flow diagram of the main model. This model is based on Causal Loop Diagram before with net income of two farmers as the main variable. Net income is the total net income of the farmer, i.e. the total amount of income that has been reduced by the total amount of expenditure per period. Expenditure is derived from the total cost of daily needs, health costs, education costs, and operational costs for farmers. Operational costs are formed from processing costs,
land rental costs, and labour costs. Labour costs are the costs for farmers who own the land, but the income for farm laborers. When it is not in a harvesting season, farmworkers also get income from other freelance jobs, such as ojek, construction workers, and land or field workers. “Farmers Net income (saving)” is established from the reduction of “farmer income rate” and “farmer expends rate” added by the initial value 55 million rupiah (Rp). Several variable formulas have shown in Table 1.

Table 1. Several examples of variable formulas configuring the model.

| No | Variable                      | Type       | Formula                                                                 | Units   |
|----|-------------------------------|------------|------------------------------------------------------------------------|---------|
| 1  | Farmers net income (saving)   | level      | INTEG (+farmer income rate - farmer expend rate) with initial value: 55000000 | Rp      |
| 2  | Farmer income rate            | rate       | farmer income from sugar                                               | Rp/month|
| 3  | Farmer expend rate            | rate       | monthly operational cost + primary education expenses × average number of family member/2 + monthly expend for every person × average number of family member × consumption pattern of farmers + healthcare expend for farmers | Rp/month|
| 4  | Farm worker net income        | level      | INTEG (farm worker income rate- farm worker monthly expend) with initial value: 1500000 | Rp      |
| 5  | Farm worker income rate       | rate       | farmer income from cane harvesting + farm workers other income         | Rp/month|
| 6  | Farm workers other income     | attribute  | (income from others freelance + other income from construction freelance + others income from “ojek”) × IF THEN ELSE (farm worker on harvesting=0, 1 , 0) | Rp/month|

Figure 3 below represents the sub model of sugar and cane production. This sub model describes that sugar production rate depends on both sugarcane volume planted and sugar yield (rendemen) of cane. There are probabilities of cane burned every year. And volumes of cane depend on total land/farm area.

Figure 3. Sugar and cane production system sub model.
Sugar stock volume in East Java besides local consumption it is also used to fulfil national needs. The stock gets supply from “sugar production rate” and imported sugar that gets into East Java. “Local consumption rate” is affected by the population of East Java. All of them are represented in Figure 4. All sub-models are integrated into large models to support the main model. They are not running separately.

3.3. Validation
After the modelling process, the next steps are simulating and validating the model. The first validation is performed by parameter testing. The parameter tested was variable of “total sugarcane area”. The model is simulated for 100 months. And recapitulation obtained a total of 8 annual sugarcane area data. The results of this simulation will be compared statistically with data sourced from BPS. 12 historical data of sugarcane land area in East Java are obtained from 2006 to 2017 as shown in Figure 5 below.
Two-sample t-test was applied to perform a hypothesis testing that computes whether two populations have statistically significant differences or not in a certain confidence interval [23]. The hypothesis is formulated as follow:

\[ H_0: \mu_1 - \mu_2 = \delta \quad \text{versus} \quad H_1: \mu_1 - \mu_2 \neq \delta \]

where \( \mu_1 \) and \( \mu_2 \) are the population means of “simulation result” and “historical data of total area planted by sugarcane”. And \( \delta \) is the hypothesized difference between the two equals to zero. The null hypothesis states that the two populations are similar or not different. Meanwhile, the alternative hypothesis states that differences exist.

**Figure 6.** Two-sample t-test result for validation.

| Two-Sample T-Test and CI: simulate; historical data |
|---------------------------------------------------|
| **Two-sample T for simulate vs historical data** |
|                                | N  | Mean | StDev | SE Mean |
| simulate                       | 8  | 201.21 | 4.27  | 1.5    |
| historical data                | 12 | 195.7  | 12.6  | 3.6    |
| **Difference = mu (simulate) - mu (historical data)**  | 5.53887 |
| **Estimate for difference:**   | 5.53887 |
| **95% CI for difference:**     | (-2.92141; 13.99916) |
| **T-Test of difference = 0 (vs not =)**: T-Value = 1.40 P-Value = 0.182 DF = 14 |

Based on the result of the two-sample t-test, P-value 0.182 was obtained. It means in \( \alpha = 0.05 \), \( H_0 \) accepted, there were no differences between the average simulation result and historical data. A 95% confidence interval is (-2.92, 13.99) which includes zero, thus suggesting that the difference doesn’t exist (statistically similar). Validation processes were obtained by the boundary adequacy test and model behaviour test as well. The model was valid.

### 3.4. Simulation and Scenario Analysis

The following are simulation results from models that have passed the validation. The simulation was run in a monthly time step. Simulations run for 100 months. Variables of “Farmers net income” and “Farmworker net income” obtained the results of the simulation as shown consecutively in Figure 7 (a) and 7 (b). Each graph fluctuates depending on the period in the harvesting season or not. In variable of “Farmworker net income” it is shown that farm workers biggest income was in the sugarcane harvesting season, they could reach more than 10 million rupiahs in saving. If it was not in harvesting season, they worked any freelance jobs, so that their income dropped dramatically.
There are gaps between the two main variables. But both of them tend to increase. As shown in Figure 8(a) and 8(b), the results of the two variables were plotted on trend analysis. This was performed to find out how big the change was over time. The linear approach was obtained. For the “Farmers net income” variable, at the early period fits 77,407,900 and at the 100th period fits 106,119,300. It means the income increased 28,711,400 in 100 months, 0.37% a month, or 4.5% a year. For “Farmworkers net income” variable, at first period fit to 4,655,200 and 100th fits 6,268,600. it means the income increased 1,613,400 in 100 months, 0.35% a month, or 4.2% for a year. Both increased by 4.3% a year on average.

**Figure 8.** (a) Trend analysis for “Farmer net income” variable. (b) Trend analysis for “Farm workers net income” variable.
After no imported sugar entry, the next step is simulating the model with the entry exist. The first scenario is carried out by a volume of 10% of the level of local sugar production and the second by an extreme volume in 60% of the level of local sugar production. 100 months running period are performed as well. Result and Comparison of them are represented in Figure 9 above. Farmer's net income from the results of scenario 1 looks lower than scenario 0 (no imported sugar entry), but the second scenario shows drastically drop in net income. Three of them show a similar level at the beginning period, but after two harvesting seasons, they look different.

Table 2. Recapitulation of three scenario condition on both main variables.

| Simulation scenario | Imported Sugar (% Volume of East Java Sugar Production Rate) | Average Of "Farmers Net Income (Saving)" (Rp) | Gap from scenario 0 (%) | Average Of "Farm worker Net Income (Saving)" (Rp) | Gap from scenario 0 (%) | Average Gab (%) |
|---------------------|---------------------------------------------------|--------------------------------|-----------------------|-----------------------------------------------|-----------------------|-----------------|
| 0                   | 0%                                                | 76,050,500                     | 0                     | 5,249,400                                     | 0                     | 0%              |
| 1                   | 10%                                               | 39,641,800                     | -47.9%                | 3,764,050                                     | -28.3%                | -38%            |
| 2                   | 60%                                               | (83,738,000)                   | -210.1%               | 1,776,300                                     | -66.2%                | -138%           |

Table 2 represents the average value of both main variables in three scenarios. All of them show that the entry of imported sugar into a province that surplus in local production as East Java harms all sugarcane farmers’ welfare. Farmers gain greater losses. As a landowner, pre-planting, planting, and harvesting processes require large costs. Misfortune for them the entry of imported sugar causes the price deals below the total production costs during the post milling auction process. Sugar sales could not cover the costs. The scenarios show that uncontrolled entry of imported sugar affects farmers’ income badly. If needed by industry, the government must make strict regulations and ensure that the imported sugar does not leak to be sold freely to end in the public market.

4. Conclusion
From the analysis of simulation model results, sugarcane farmers' income threatened with the entry of imported sugar in east java. The simulation results that if there are imported sugar get into East Java
with 10% of local sugar volume production, sugarcane farmers’ income will decrease 38% per year on average. When the entry of imported sugar into East Java goes out of control, for example, 60% of local sugar production, the average annual income of sugar cane farmers will drastically decrease. But when imported sugar does not enter, the income of smallholder sugarcane farmers creeps up 4.3% on average. When the entry of imported sugar into East Java goes out of control, for example, 60% of local sugar volume production, sugarcane farmers' income will decrease 38% per year on average. Therefore, it is hereby recommended for Government especially the Local Government of East Java Province to tighten the entry of imported sugar into East Java to protect the welfare of sugarcane farmers.

Acknowledgement

The authors would like to acknowledge colleagues in the Industrial Engineering Laboratory of Universitas Maarif Hasyim Latif Sidoarjo for the facilitations in developing the models.

References

[1] Putra A B and Suryani E., (2014). Skenario Kebijakan Industri Gula Untuk Meningkatkan Ketersediaan Gula Dipasaran Dengan Menggunakan Pendekatan Sistem Dinamik. Sisfo. 05, 01 p. 51–61. doi.org/10.24089/j.sisfo.2014.03.013

[2] Bagus S, (2019). Petani Tebu Dukung Kebijakan Gula Nasional, Media Indoensia E-Paper (https://mediaindoensia.com/read/detail/221902-petani-tebu-dukung-kebijakan-gula-nasional). [Online]. Available: https://mediaindoensia.com/read/detail/221902-petani-tebu-dukung-kebijakan-gula-nasional. [Accessed: 20-Feb-2020].

[3] Kumalasari A D Budiraharjo K and Setiadi A., (2019) Komparasi Produksi dan Pendapatan Petani Tebu Mitra dan Non Mitra Fabrik Gula Rendeng di Kabupaten Kudus. Agrisocionomics: Jurnal Sosial Ekonomi Pertanian. 3, 1 p. 28. doi.org/10.14710/agrisocionomics.v3i1.4021

[4] Sadikun S., (2019). Sejauh Mana Jawa Timur Wujudkan Swasembada Gula Nasional 2019?, Mediajatim.com. [Online]. Available: https://mediajatim.com/2019/10/15/sejauh-mana-jawa-timur-wujudkan-swasembada-gula-nasional-2019/. [Accessed: 20-Feb-2020].

[5] Asrol M, Marimin M, Machfud M, Yani M, Taira E. Supply Chain Fair Profit Allocation Based on Risk and Value Added for Sugarcane Agro-industry. Oper. Supply Chain Manag Int. J. OSCM Forum; 2020 Mar 12;150.

[6] Shongwe M I and Bezuindenhout C N., (2018). A heuristic for the selection of appropriate diagnostic tools in large-scale sugarcane supply systems. AIMS Agric. Food 4, 1 p. 1–26. doi.org/10.3934/AGRFOOD.2019.1.1

[7] Ima Dudin M D Wiranatha A S and Sadyasmara C A B., (2020). Simulasi Model Sistem Dinamik Ketersediaan Bawang Putih (Allium sativum, L.) di Provinsi Bali. Jurnal Rekayasa Dan Manajemen Agroindustri. 8, 1 p. 114. doi.org/10.24843/JRMA.2020.v08.i01.p12

[8] Seeler K A., (2014). Introduction to System Dynamics. Syst. Dyn., (New York, NY: Springer New York), p. 1–44. doi.org/10.1007/978-1-4614-9152-1_1

[9] Feofilovs M Gravelsins A Pagano A J and Romagnoli F., (2019). Increasing resilience of the natural gas system with implementation of renewable methane in the context of Latvia: A system dynamics model Energy Procedia 158 p. 3944–3950. doi.org/10.1016/j.egypro.2019.01.848

[10] Forrester J W and Collins F, Dec. (1972). World Dynamics J Dyn Syst Meas Control. 94, 4 p. 339–339. doi.org/10.1115/1.3426619

[11] Dewi N, Miharja M and Yudoko G., (2015). Analisis Kebijakan Distribusi Bahan Baku Rotan Dengan Pendekatan Dinamik Sistem Studi Kasus Rotan Indonesia Jurnal Perencanaan Wilayah dan Kota 26, 3 p. 177–191. doi.org/10.5614/jp/wk.2015.26.3.3

[12] Forrester J W., (1994) System dynamics, systems thinking, and soft OR System Dynamics Review 10, 2–3 p. 245–256. doi.org/10.1002/sdr.4260100211

[13] Budi Supangat A, Sudira P, Supriyo H and Poedirahajoe E., (2018). Simulasi Model Dinamik
Pengaruh Legume Cover Crops (LCC) Terhadap Limpasan Dan Sedimen Di Lahan Hutan Tanaman Jurnal Penelitian Pengelolaan Daerah Aliran Sungai 2, 1 p. 17–34. doi.org/10.20886/jppdas.2018.2.1.17-34

[14] Forrester J W. (2016). Learning through System Dynamics as Preparation for the 21st Century Syst. Dyn. Rev. 32, 3–4 p. 187–203. doi.org/10.1002/sdr.1571

[15] Shreckengost RC. Dynamic simulation models: how valid are they? PsycEXTRA Dataset. American Psychological Association (APA); 1985; Available from: http://dx.doi.org/10.1037/e496952006-007

[16] Hasan N, Suryani E, Hendrawan R. Analysis of Soybean Production and Demand to Develop Strategic Policy of Food Self Sufficiency: A System Dynamics Framework. Procedia Comput. Sci. Elsevier BV; 2015;72:605–12. doi.org/10.1016/j.procs.2015.12.169

[17] Oktyajati N, Hisjam M and Sutopo W. (2018). The dynamic simulation model of soybean in Central Java to support food self sufficiency: A supply chain perspective in AIP Conference Proceedings p. 030015. doi.org/10.1063/1.5024074

[18] Ouyang Y, Xu D, Leininger TD, Zhang N. A system dynamic model to estimate hydrological processes and water use in a eucalypt plantation. Ecol. Eng. Elsevier BV; 2016 Jan;86:290–9. doi.org/10.1016/j.ecoleng.2015.11.008

[19] Marín-González O, Parsons D, Arnes-Prieto E, Diaz-Ambrona CGH. Building and evaluation of a dynamic model for assessing impact of smallholder endowments on food security in agricultural systems in highland areas of central America (SASHACA). Agric. Syst. Elsevier BV; 2018 Jul;164:152–64. doi.org/10.1016/j.agsy.2018.02.005

[20] Rich K M, Rich M and Dizyee K, (2018) Participatory systems approaches for urban and peri-urban agriculture planning: The role of system dynamics and spatial group model building Agric. Syst. Elsevier BV; 2018 Feb; 160 p. 110–123. doi.org/10.1016/j.agsy.2016.09.022

[21] Demczuk A and Padula A D., (2017). Using system dynamics modeling to evaluate the feasibility of ethanol supply chain in Brazil: The role of sugarcane yield, gasoline prices and sales tax rates Biomass Bioenergy 97 p. 186–211. doi.org/10.1016/j.biombioe.2016.12.021

[22] Yunitasari D, Lestari E K and Istiyani N., (2018). Analisis Potensi Tebu dalam Mendukung Pencapaian Swasembada Gula di Kabupaten Bondowoso Buletin Tanaman Tembakau, Serat & Minyak Industri 10, 1 p. 13. doi.org/10.21082/btsm.v10n1.2018.12.021

[23] Gerald B., (2018). A Brief Review of Independent, Dependent and One Sample t-test Int. J. Appl. Math. Theor. Phys. 4, 2 p. 50. doi.org/10.11648/j.ijamtp.20180402.13