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THE DEVELOPMENT OF SYSTEM DYNAMICS MODEL TO ANALYZE AND IMPROVE THE PRODUCTION OF CRUDE PALM OIL DERIVATIVES

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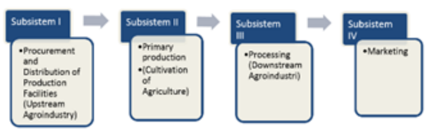
Erma Suryani[a]*, Rully A. Hendrawan[a], Suryo Atmojo[a], Lily P. Dewi[b]

[a]Institut Teknologi Sepuluh Nopember, Indonesia
[b]Petra Christian University, Surabaya, Indonesia

*Corresponding author
erma.suryani@gmail.com

Graphical abstract



Abstract

Indonesia is one of the largest palm oil producer in world. The products of palm oil derivative diverse, ranging from cooking oil, margarine, soap, and biodiesel. So far, Indonesia is more likely to export Crude Palm Oil (CPO) to various countries. But on the other hand, Indonesia need to reduce the burden imports of some palm oil derivative products such as cooking oil, biodiesel, and soap. It is therefore, we need a breakthrough to improve the production of crude palm oil and its derivative products so that we can increase the availability of the derivative products. Based on this existing condition, we need an approach that can analyze the use condition of the palm oil derivative products and improve the palm oil use of derivative products in the future. Therefore, in this research, we will develop a model that can analyze and develop some policy scenarios to improve the utilization of palm oil derivative products. The method used for the model development is system dynamics, based on the ability to accommodate the internal and external factors that affect the production of palm oil derivative products.From the model scenarios we obtained that by sorting the fruits harvested, so that the levels of Oil Extraction Rate is at 22.1%, it can increase the stock of CPO by 11%. By utilizing 50% of CPO for the cooking oil production will meet the needs of the national cooking oil demand, with a ratio of 1.5 fulfillment began in 2010. If we utilize 35% of CPO to be processed as stearin, and use 10% of stearin in the soap contain, it will fulfill the need of domestic soap until 2015. By utilizing the empty fruit bunches waste as raw material for biodiesel, there will be additional biodiesel production of around 920,479 kilolitres in 2019. Meanwhile, the use of 1% of CPO production to create biodiesel, it will make biodiesel production reaches 31,173 kilolitres in 2019. From these efforts, there will be 951,652 kilolitres biodiesel production in 2019.

Keywords: Crude palm oil (CPO), system dynamics, downstream CPO, scenario models

1.0 INTRODUCTION

Currently the Indonesian palm oil industry has grown significantly [1]. From the data of the Ministry of Agriculture Directorate General of Plantations can be concluded tendency palm oil production each year is always increase. Nearly 90% of world palm oil production was produced by Indonesia; this data is presented by the Ministry of Agriculture Directorate General of Plantation [1]. Based on information from the Ministry of Industry, palm oil can be processed into food and non-food industry. The palm fruit can be processed into Crude Palm Oil (CPO) that can be used as a raw material of cooking oil. Non-food palm processing including produce detergents, soaps and biodiesel.

Based on the data from the Central Bureau of Statistics, the tendency of crude palm oil exports tend to decline. Meanwhile, the demand of fuel in Indonesia itself tend to increase. The Central Bureau of Statistics showed that gasoline demand in 2000 reached 12,412,820 kilolitres slowly starting to rise so that by the year 2011 amounted to 26,447,230 kilolitres. Diesel fuel demand also have a rising trend. Meanwhile, the demand of diesel fuel in Indonesia at the end of 2011 amounted to 26,391,275 kilo litres. Based on these condition, it requires special attention on the production of processed palm oil in order to improve the utilization of the processing of palm oil derivative products.

The previous research using a dynamic model showed the behavior of CPO supply chain system for the next 30 years [1]. The CPO sales tend to increase in the future. This increase is due to the domestic demand continues to rise due to the increased population.

2.0 EXPERIMENTAL

Palm oil is an important plantation crop to be produced as food, cooking oil, and biofuels (biodiesel) [2]. Agribusiness system in the palm oil are grouped into four subsystems, namely the provision of production (agro-industry upstream), primary production activities (cultivation), processing (downstream agro-industries), and marketing, as shown in Figure 1 [3].

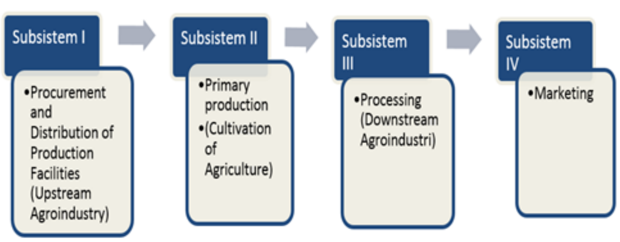


Figure 1 Agribusiness System

The agro-industry upstream of palm plantations produce primary products such as crude palm oil (CPO) and palm kernel oil. Out of these, many products could be derived. CPO can be derived into several products such as olein and stearin. The main products of refined olein are cooking oil while refined stearin products are soap and margarine. Palm oil itself can be processed into biodiesel. The needs of cooking oil or vegetable oil has increased every year. CPO oil consumption should be supported by the palm oil processing to produce diversity in oil-based commodities, including edible oils [4].

3.0 MODEL DEVELOPMENT

To develop a system dynamics model, causal loop diagram (CLD) is required as framework for the model development. Furthermore, some steps in developing system dynamics are: 1) system understanding; 2) system conceptualization (CLD development); 3) converting CLD into a flow diagram for the simulation process; 4) model validation, 5) scenario development. The causal loop diagram that describes the use of Crude Palm Oil (CPO) can be seen in Figure 2.

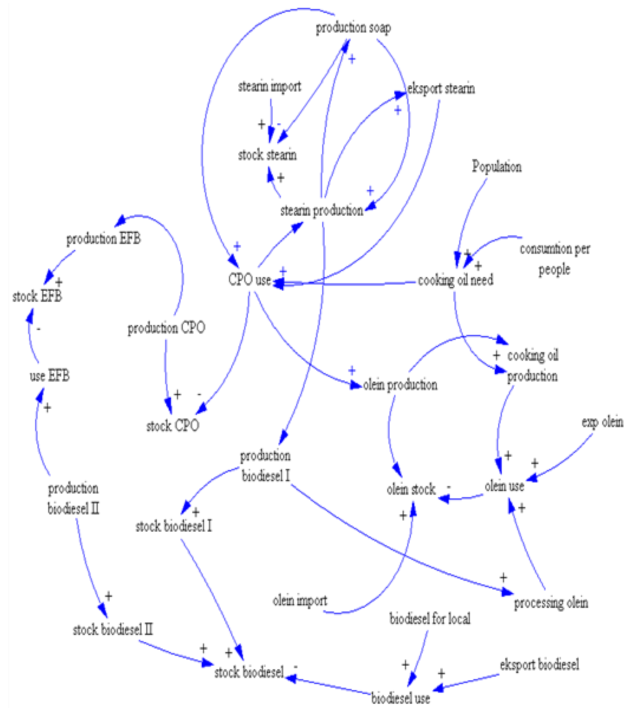


Figure 2 Causal Loop Diagram [1]

Based on the above diagram, we can see that Crude Palm Oil (CPO) can be processed into olein and stearin. We may use olein as the raw material of cooking oil. Meanwhile we can utilize stearin for soap and biodiesel. CPO production also generates waste production. One of the waste product is empty fruit bunches. Empty fruit bunches can be reprocessed into biodiesel to reduce imports of diesel fuel.

3.1 Planted Area Sub Model

Palm planted area is one of the factors that influence the production of CPO. By knowing the Indonesian palm planted area, it can be used to determine the productivity of the land. Total planted area is the summation of industry and local planted area as seen in Eq. (1).

"Total planted area (ha) BM"= "industry planted area (ha) BM"+"local planted area (ha) BM" (1)

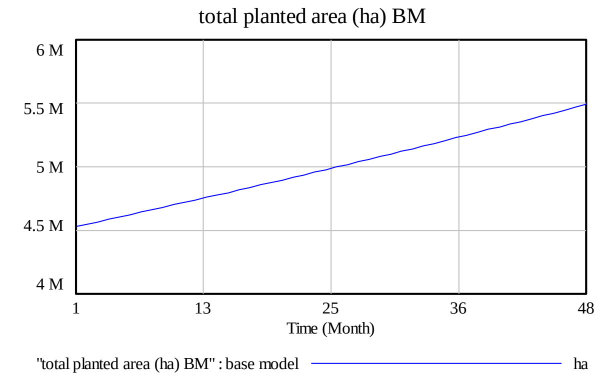


Figure 3 Total Planted Area

The simulation of planted area can be seen in Figure 3. From Figure 3, it can be seen that the total land area reached 5.5 million hectares in 2012.

3.2 CPO Production Sub Model

CPO production in Indonesia from year to year have a tendency to increase. CPO production is influenced FFB production (Fresh Fruit Bunches) and Oil Extraction Rate (OER) in all fractions (fraction 0 - 5) as depicted in Eq. (2)

"Production of CPO (Ton) BM" = "Production of FFB (Ton/mo) BM"*OER BM/100 (2)

OER is divided by the fraction, as seen in Table1.

Table 1 Palm Oil Fraction

Fraction	Characteristic	OER %
0	Raw	16
1	Under ripe	21.4
2	Ripe	22.1
3	Ripe	22.2
4	Over ripe	22.2
5	Over ripe	21.9

Figure 4 shows the simulation results of fresh fruit bunches production from 2009 until 2012. From Figure 4, it can be seen that the CPO production was ranging from 1.6 M – 2.1 M Ton.

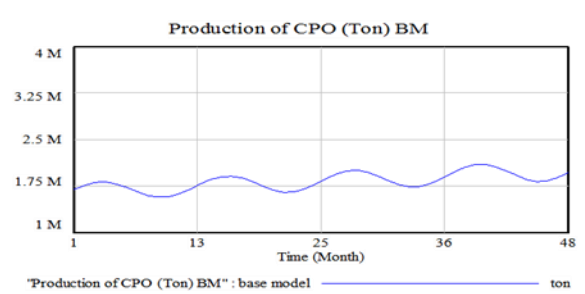


Figure 4 CPO Production

3.3 Cooking Oil Production Sub Model

Figure 5 is the simulation result of cooking oil production from 2009-2012. From Figure 5, it can be seen that the average of cooking oil production increase is about 2.5% per month. Cooking oil production depends on the net growth rate of cooking oil as seen in Eq. (3)

cooking oil production = $\int rate\ in\ cooking\ oil\ prod. - rate\ out\ cooking\ oil\ prod.$ (3)

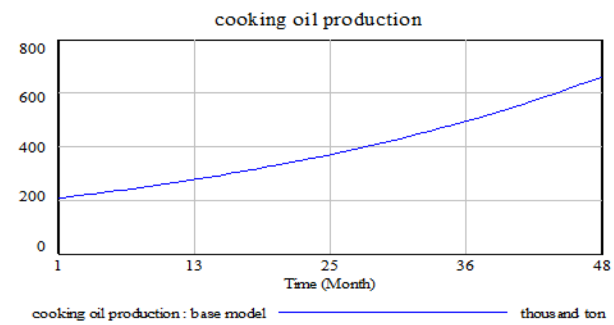


Figure 5 Cooking Oil Production

3.4 Soap Production Sub Model

This sub model is made to check demand and soap production. The demand of soap includes the demand for local soaps and for export. Figure 6 shows a comparison between the demand and the production of soap starting in 2009-2012. From Figure 6, it can be seen that during this period, the demand of soap is still higher than its production. Soap production depends on the net growth rate op soap production as seen in Eq. (4)

total soap production = $\int$ "rate in soap producion (kilo ton)" − "rate out soap production (kilo ton)" (4)

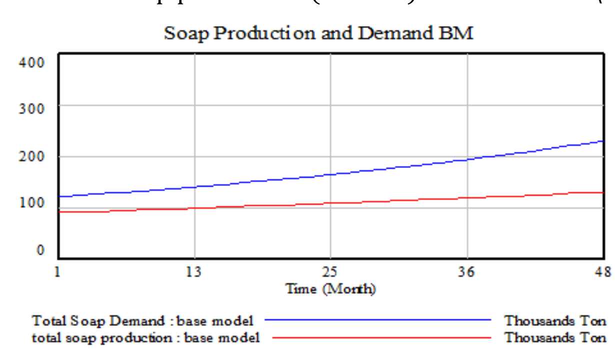


Figure 6 Soap Production and Demand

3.5 Biodiesel Sub Model

Figure 7 shows the simulation results of biodiesel production starting in 2009-2012. As we can see from Figure 7, it can be seen that the average production of biodiesel increased by 4.5% per month. Biodiesel production depends on the net growth rate of soap production as seen in Eq. (5)

"Biodiesel production per month (kilo liter) BM"= ∫ "rate in biodiesel production (kilo liter/mo) BM"-"rate out biodiesel production (kilo liter/mo) BM" (5)

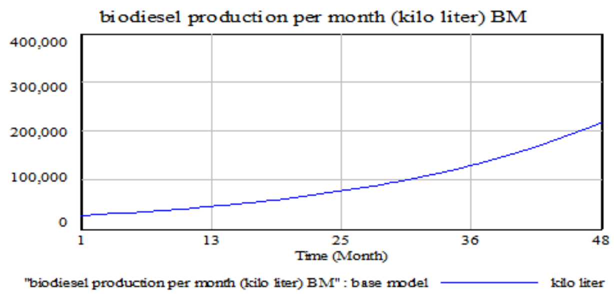


Figure 7 Biodiesel Production

4.0 MODEL VALIDATION

Model validation is required to check the model validity. A model will be valid if the error rate is less than 5% and error variance is less than 30% [5]. Error rate and error variance are defined in Eq. (6) and (7):

$$ErrrorRate = \frac{[\bar{S} - \bar{A}]}{\bar{A}} \quad (6)$$

$$ErrorVariance = \frac{|Ss - Sa|}{Sa} \quad (7)$$

Where :

$\bar{S}$ = the average rate of simulation
$\bar{A}$= the average rate of data
S_s= the standard deviation of simulation
S_a= the standard deviation of data

Error rate of Land Area for both Large and People Plantation, CPO Production, Cooking Oil Production, and Soap Production are depicted as follows:

Error rate of CPO Production

$$= \frac{[1922.45 - 1967.72]}{1922.45} = 0.0235$$

Error rate of Cooking Oil Production

$$= \frac{[408.83 - 391.83]}{408.83} = 0.0416$$

Error rate of Soap Production

$$= \frac{[107.17 - 107.76]}{107.17} = 0.005$$

Error Variance of Land Area for both Large and People Plantation, CPO Production, Cooking Oil Production, and Soap Production are depicted as follows:

Error variance of CPO Production

= ([136.24-179.57])/179.57=0.24

Error variance of Cooking Oil Production

= ([133.91-140.16])/140.16=0.04

Error variance of Soap Production

= ([11.88-10.97])/10.97=0.08

From the above calculation we can see that all of the errors rate are less than 5% and the errors variance are less than 30%, which means that our model is valid.

5.0 SCENARIO DEVELOPMENT

Scenario is required to improve the system performance. In this case the scenarios are designed to improve the utilization of oil into derivatives such as cooking oil, soap and biodiesel.

5.1 Sorting the Harvested Fruits

In this scenario, the harvested oil palm fruit is ripe fruit with Oil Extraction rate (OER) content of 22.1%. From this scenario, we obtained that by sorting the harvested fruits, so that the levels of Oil Extraction Rate is at 22.1%, it can increase of the CPO production by 11% as shown in Figure 8.

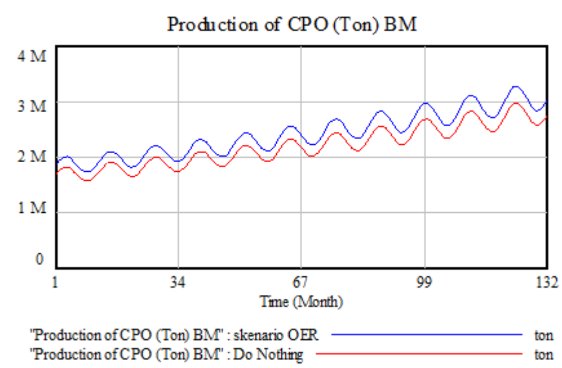


Figure 8 The Scenario Comparison of CPO Production before and after sorting process of the Harvested Fruits

5.2 Sorting the Harvested Fruits

The average CPO demand for producing cooking oil is about 50% of the total production of CPO. This value was obtained from the average ratio of cooking oil consumption data and projections towards CPO demand for 20 years (2009 to 2028). From this scenario, it is known that by utilizing 50% of national CPO production, the fulfilment ratio of CPO cooking oil will reach 1.5 as shown in Figure 9.

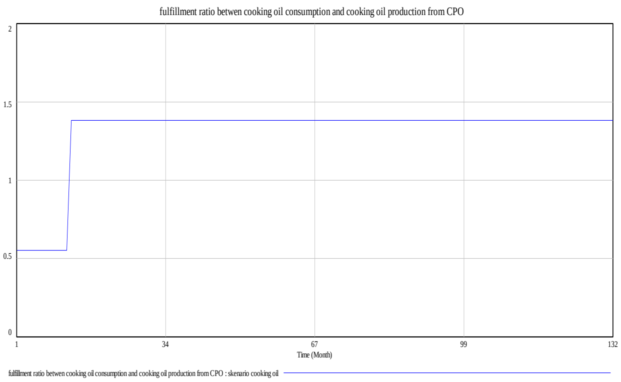


Figure 9 Fulfilment Ratio of Cooking Oil Production and Consumption

5.3 The Use of CPO into Soap

If we utilize 35% of CPO to be processed as stearin, and use 5% stearin in the local soap production; 5% stearin in the exported soap production; 25% as exported stearin; it will fulfil the need of domestic soap until the period of 78 (year 2015), as shown in Figure 10.

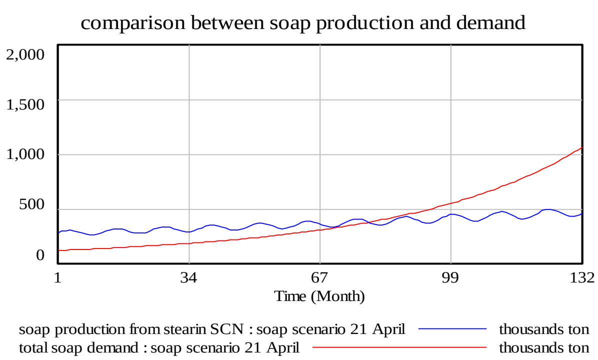


Figure 10 Soap production and demand

5.3 The Use of CPO into Soap

This scenario was developed by utilizing empty fruit bunches waste as raw material for biodiesel and 1% of CPO production is used for biodiesel production.

By utilizing the empty fruit bunches waste as raw material for biodiesel, there will be additional biodiesel production of around 920.479 kilolitres in 2019. Meanwhile, the use of 1% of CPO production to create biodiesel, it cause biodiesel production will reach 31.173 kilolitres in 2019. Therefore, totally there will be 951.652 kilolitres of biodiesel production in 2019 as seen in Figure 11.

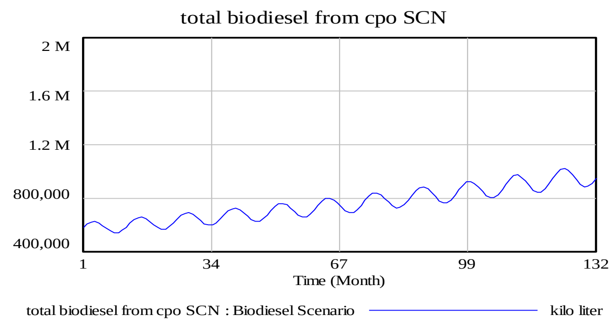


Figure 11 Total Biodiesel

6.0 CONCLUSIONS

1. Deep understanding of system is needed so that the resulting system dynamic models can approach reality system.
2. This paper presents a framework for the development of system dynamic models and scenarios to improve the utilization of palm oil for cooking oil products, soaps, and biodiesel.
3. By increasing the utilization of palm oil for cooking oil consumption e, the ratio of fulfillment of cooking oil increased to 1.5.
4. If we utilize 35% of CPO to be processed as stearin, and use 5% stearin in the local soap contain; 5% stearin in the export soap contain; 25% exported stearin; it will fulfill the need of domestic soap until the period of 78 (2015).
5. By utilizing the empty fruit bunches waste as raw material for biodiesel, there will be additional biodiesel production of around 920,479 kilolitres in 2019. Meanwhile, the use of 1% of CPO production to create biodiesel, it will make biodiesel production reach 31,173 kilolitres in 2019. From these efforts, totally there will be 951,652 kilo liter biodiesel production in 2019.

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