Dynamic Simulation Model of Crude Palm Oil Supply Chain to Determine Fulfillment Ratio and Manufacturing Efficiency of Cooking Oil Industry

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Abstract

Palm oil is one of national commodities that contribute significantly to national economy. Demand for palm oil will increase with the increase of population, so that demand for palm oil as a raw material of cooking oil will also increase. So far, Indonesia is more likely to export Crude Palm Oil (CPO) to various countries. From 100 downstream products of palm oil industry, only about 23 kinds of downstream products that have been produced commercially in Indonesia. Some problems faced in the palm oil industry include the following: 1) the low productivity of fresh fruit bunches; 2) the limited industrial downstream; 3) policies that are not conducive; and 4)the lack of palm oil fruit processing plant. Therefore, in this study we develop a system dynamics model to improve the productivity and efficiency of cooking oil supply chain as one of the downstream processed products. As the method used in model development, we utilized system dynamics simulation based on consideration that system dynamics (SD) has been widely used in industry, macro-economic planning, social development, environment and other fields. This method emphasizes on integrity and nonlinear properties of complex systems that very suitable to model crude palm oil supply chain. Research results show that land expansion and replanting will influence the increasing rate of palm oil land area. Total land area is a summation of immature land area, yield land area, and land with crop age over 25 years. The productivity of palm oil land is influenced by the adequacy of fertilizer, humidity, precipitation, temperature, and sun lighting. Meanwhile, the production of fresh fruit bunches depends on land area and land productivity. Fulfillment ratio of cooking oil is greater than 100%, which means that we can fulfill our national demand

Key words Crude Palm Oil, model, scenario, supply chain, cooking oil industry

1. INTRODUCTION

Palm oil is one of national commodities that contribute significantly to national economy. Demand for palm oil will increase along with the increase of population, so that palm oil demand as a raw material of cooking oil will also increase. Palm oil downstream industry type spectrum is very wide, up to more than 100 downstream products can be produced on an industrial scale. However, only about 23 kinds of downstream products that have been produced commercially in Indonesia. Some downstream derivative products that have been produced such as: cooking oil, margarine, Cocoa Butter Substitute (CBS), food emulsifier, fat powder, and ice cream. In this research, we focused on palm oil derivative products such as cooking oil as the main commodity in Indonesia. In palm oil plantations, there is a gap between the productivity of smallholder plantations (13.61 tons of FFB / ha / year) with government plantation (16.98 tons of FFB / ha / year) and private plantation (16.69 tons of FFB / ha/year) [1]. From the historical data of palm oil plantations, approximately 57% owned by the private sector, 30% owned by independent smallholders, and 13% state owned. So far, Indonesia is more likely to export Crude Palm Oil (CPO) to many countries such as India, China, the Netherlands, Malaysia and Singapore [2]. With the increase in exports, the CPO supply to the domestic market will be reduced. Some problems faced in palm oil industry include the following:

1. Low productivity of fresh fruit bunches (FFB). Indonesian palm oil productivity is lower compared to Malaysia. Indonesia has an average productivity of oil palm FFB amounted to 14-16 tons/ha/year. While Malaysia has the FFB productivity of 18-21 tons/ha/year.
2. Limited industrial downstream. Currently the downstream industry has not developed due to the unfavorable investment climate.
3. Policies that are not conducive. The rising price of CPO in the international market caused many domestic manufacturers exporting CPO, rather than sell CPO domestically. One of the efforts made by the government is to increase the export tax (PE) for CPO from 1.5% to 6.5% and an increase in export tax of fresh palm (FFB) by 10% from the previous 3%. The impact of this policy among which the reduction in income, palm oil producers, benefiting exporters, disrupting the inevestment climate [3].
4. Lack of oil palm fruit processing plant. This resulted into rotting palm fruit and farmers lose money. In 22 provinces cultivate palm oil in Indonesia, there are 420 palm oil mills scattered in the area of oil palm

plantations. But there are some provinces that do not have a palm oil processing plant but has oil palm plantations, such as in Southeast Sulawesi [3] .

The use of palm oil as a raw material development of industry can provide multiple effects [4]: 1) the growth of other economic sub-sector; 2) the development of industrial areas; 3) the technology transfer process; 4) expansion of employment opportunities; 5) foreign exchange earnings; 6) increase in tax revenue. Ministry of Industry has set a target in the palm oil industry to increase the added value of commodities, investment and foreign exchange revenue and create more jobs. Therefore, in this study we will develop models of crude palm oil supply chain to determine the ratio of fulfillment of cooking oil and cooking oil fabrication industry efficiency.

2. LITERATURE REVIEW

Supply chain management is a mechanism to increase total productivity of companies in the supply chain by optimizing material flow quantity, location, and time [5]. The supply chain component [2] includes suppliers of raw materials, palm oil producers, domestic customer, overseas customer and environment (forest) as shown in **Figure 1**. Suppliers consist of palm oil plantations owned by farmer (smallholder) of around 2,565,000 ha (38.7% of national palm oil plantations), state-owned palm oil of around 687,000 ha (10.3% of national land area), and private enterprises of arounf 3,358,000 ha (50.7% of national land area) [6]. Environment (forest) is a subsystem of CPO supply chain related to the consequences of deforestation due to palm oil industry.

Total national CPO production, 52.5% is the production of private enterprises, 33.9% of smallholder, and 13.5% of government companies. Local Customers utilize CPO as raw material for processed products, such as industrial cooking oil, oleo chemicals, soap and margarine. Overseas Customers consist of several countries including India, China, the Netherlands, Malaysia and Singapore.

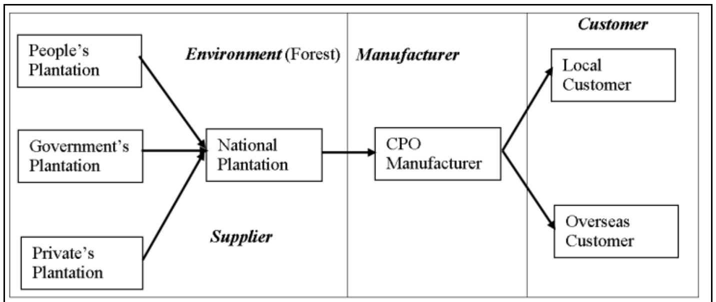

Figure 1. Supply Chain Management of Crude Palm Oil [2]

Today, Indonesia has about 23 different types of derivative products that have been produced. Given the potential of Indonesia's palm oil and CPO production in 2010 that has reached 20 million tons, Indonesia need to enhanced derivative products [7]. With this CPO processing into a variety of derivative products, it will provide greater added value for the country because the price is relatively expensive. Currently the use of CPO in Indonesia is still relatively low at around 35% of total production.

3. BASE MODEL DEVELOPMENT

In this section, we demonstrate model development of cooking oil supply chain model that include the following:

3. 1. Area Plantation Submodel. Palm plantation area can be classified into several types by considering the age of the planting, which consist of immature area, crops yield area, damage crop area, area with plant age over 25 years, and area with uncertified seed as seen in **Figure 2**.

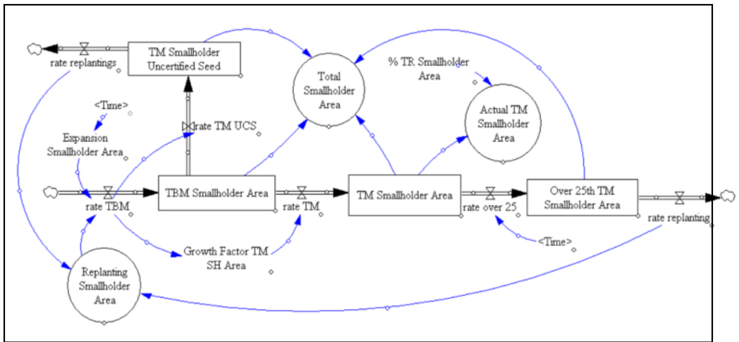

Figure 2. Flow Diagram of Smallholder Plantation

From the simulation results, we obtain smallholder plantation area in 2015 was around 4,846,147 ha; palm plantation area owned by the government was around 775 738 ha; and private plantation was approximately 5,871,815 ha.

3. 2. Land Productivity Submodel. Figure 3 shows a flow diagram of land productivity. As we can see from **Figure 3**, land productivity is affected by the adequacy of fertilizer, humidity, precipitation, temperature, and lighting. The average productivity of small holder area in the period of 2000-2015 was around 17.15 tons / ha; government land area was around 20 tons / ha, and private land was around 20 tons/ha as seen in **Figure 4 - 6.**

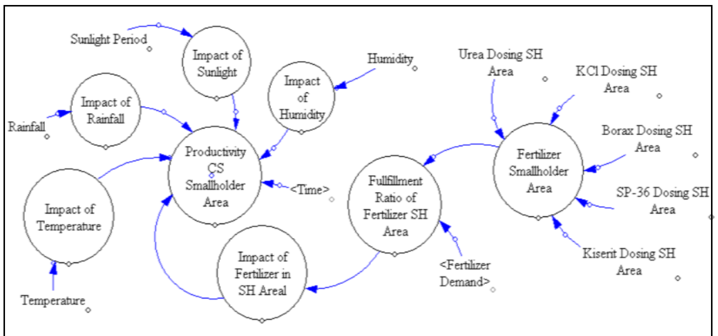

Figure 3. Flow Diagram of Land Productivity

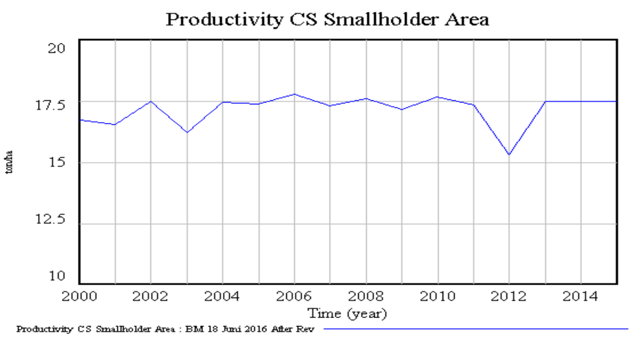

Figure 4. Small Holder's Area Productivity

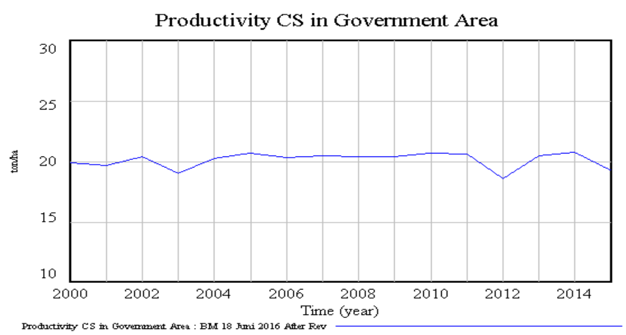

Figure 5. Government's Area Productivity

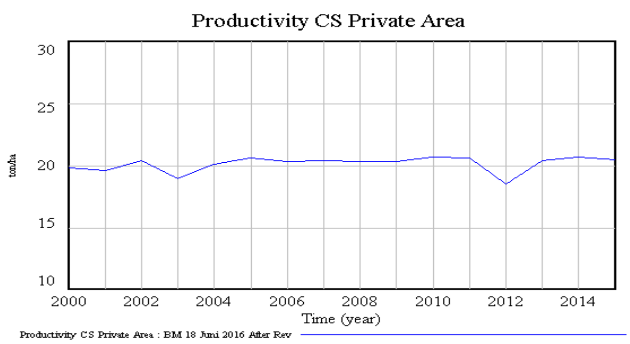

Figure 6. Private's Area Productivity

3. 3. Crude Palm Oil Production Submodel. **Figure 7** shows the flow diagram of crude palm oil production. As we can see from **Figure 7**, Crude Palm Oil (CPO) production is influenced by the production of fresh fruit bunches that may come from three sources (certified seed, uncertified seed, and plants over 25 years) and oil extraction rate as shown in Equation (1).

Smallholder CPO Production = ((FFB Production from Certified Seed+FFB Production from Over 25th CS)*OER Certified Seed) + (FFB Production from Uncertified seed*OER Uncertified Seed)	(1)

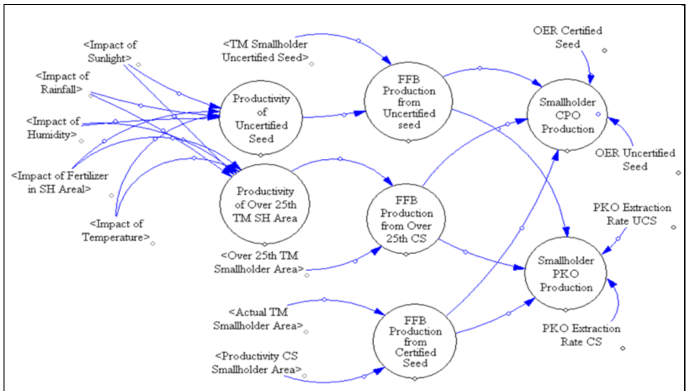

Figure 7. Flow Diagram of Crude Palm Oil (CPO) Production

Simulation results show that small holder's CPO production in 2015 was around 11,536,568 tons, government's production was around 2,186,011 tons, and private production was around 16,292,367 tons.

4. 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% [8]. Error rate and error variance are defined in Equation (2) and (3).

$$ErrrorRate = \frac{\left[\bar{S} - \bar{A}\right]}{\bar{A}}$$	(2)
$$ErrorVariance = \frac{\lvert Ss - Sa \rvert}{Sa}$$	(3)

Where :

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

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

Ss= the standard deviation of simulation

Sa= the standard deviation of data

We provide the average rate of simulation results, average rate of data, standard deviation of simulation, and standard deviation of data in **TABLE 1** and **TABLE 2** to determine the Error Rate and Error Variance of land area and CPO production.

TABLE 1. Error Rate Determination

Variabel	**Average of Simulation ($\bar{S}$)**	**Average of Data ($\bar{A}$)**	**Error Rate**
Land Area	2985842	2946136	0.010
CPO Production	6613934	6564933	0.007

TABLE 2. Error Variance Determination

Variabel	**Standard Deviation of Simulation (S_s)**	**Standard Deviation of Data (S_a)**	**Error Variance**
Land Area	1163057	1116718	0.041

CPO Production	2725350	3002787	0.092

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

5. COOKING OIL PRODUCTION AND SUPPLY CHAIN MODEL

Figure 8 represents the flow diagram of cooking oil production. As we can see from **Figure 8**, cooking oil raw materials can be derived from CPO production and the percentage of CPO used for raw material of cooking oil.

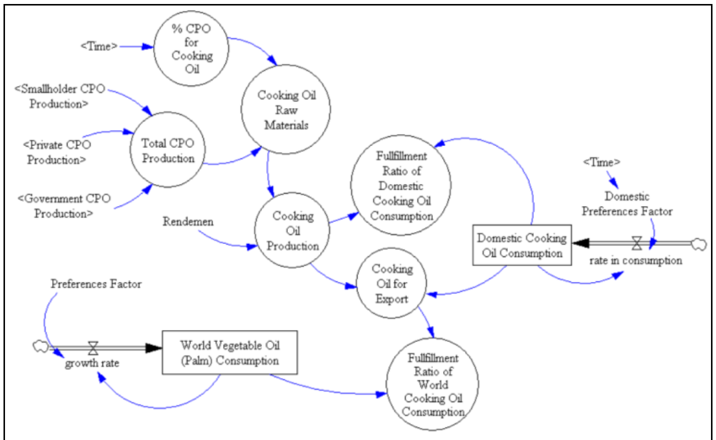

Figure 8. Flow Diagram of Cooking Oil Production

In addtion, this raw material will be processed into cooking oil with a rendement of around 73.8%. Fulfillment ratio is the ratio of cooking oil production and cooking oil demand. The fulfillment of cooking oil in Indonesia is greater than 100% as seen in **Figure 9**.

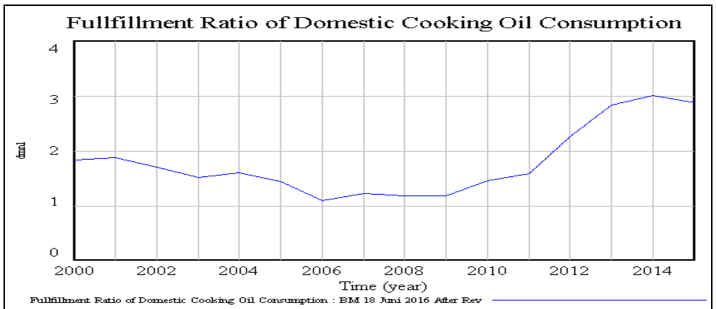

Figure 9. The Fulfillment Ratio of National Cooking Oil

Figure 10 shows cooking oil supply chain model which includes cooking oil prices at manufacturer level, distributor level, wholesaler level, and retailer level. The production capacity of cooking oil per day is 1000 tons [9], so that in a year with an average of 25 days work per month (25 * 12 = 300 days) could produce 300,000 tons of CPO per year. Simulation results show that the efficiency of cooking oil production was around 1.1 as shown in **Figure 11**.

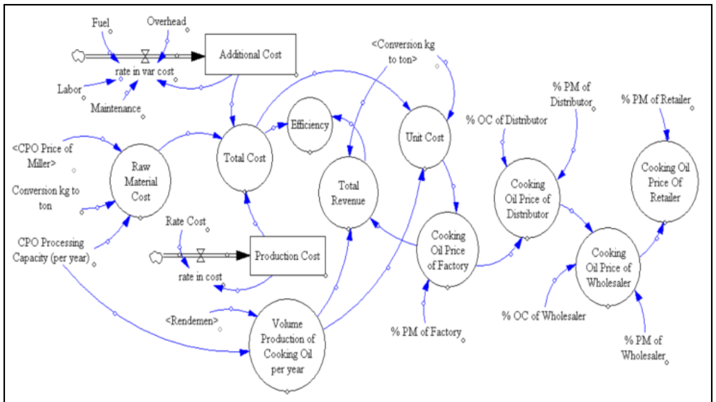

Figure 10. Cooking Oil Supply Chain Model

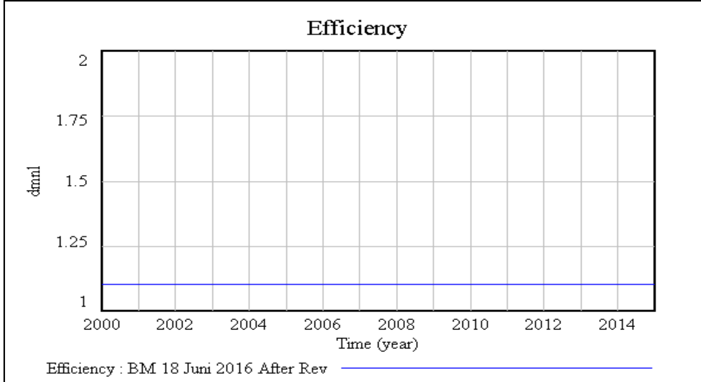

Figure 11. The efficiency of Cooking Oil industry

6. CONCLUSION

In developing system dynamics model, it is required to have a high system understanding to identify the system behavior. This system understanding will assist modelers in developing the model flow diagram and creating a valid model.

In the first phase, the area of palm oil has not produced, until the period of about three years. The rate of increase in immature areas is affected by the land expansion and replanting process. The total land area is the summation of immature land area, yield land area, and land with crop age over 25 years. The total area of productive land is influenced by the area of plantation crops and the percentage of land area that suffered damage.

In addition, the productivity of palm oil land depends on the adequacy of fertilizer, humidity, precipitation, temperature, and sun lighting. The production of fresh fruit bunches is affected by the area of productive land and land productivity.

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