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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. Indonesia is also facing low productivity of Fresh Fruit Bunches (FFB). Indonesian palm oil productivity is lower compared to Malaysia. Based on the data indonesia has an average productivity of oil palm FFB of around 14-16 tons/ha/year while Malaysia has the FFB productivity of 18-21 tons/ha/year. Some problems faced in the palm oil industry include the following: the low productivity of fresh fruit bunches, the limited industrial downstream, policies that are not conducive and the lack of palm oil fruit processing plant. Therefore, in this study we develop a system dynamics model to improve land productivity owned by smallholder (farmer) and determine the efficiency of cooking oil supply chain as one of the downstream processed products. Improving productivity can be done through a balanced fertilizer, the use of quality seeds on replanting. The efficiency of cooking oil supply chain depends on total production cost and total revenue. 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, precipitation

INTRODUCTION

Palm oil is one of national commodities that contribute significantly to national economy. The increasing demand of palm oil will be in accordance to the increasing 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) (BAPPENAS., 2010). 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,

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the Netherlands, Malaysia and Singapore (Widodo *et al*., 2010). 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.

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.

Limited industrial downstream: Currently the downstream industry has not developed due to the unfavorable investment climate.

Policies 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 1.5-6.5% and an increase in export tax of fresh palm bunches (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 investment climate (Herianto, 2008).

Lack of oil palm fruit processing plant: This resulted palm fruit become rotten 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 (Herianto, 2008).

The use of palm oil as a raw material development of industry can provide multiple effects (GCSL., 2009): the growth of other economic sub-sector, the development of industrial areas, the technology transfer process, expansion of employment opportunities, Foreign exchange earnings, 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. According to the Directorate General of Plantation of the Ministry of Agriculture there are about 50% of oil palm plantations owned by smallholder (farmer) that should be immediately re-planting (MAFW., 2015). Meanwhile, CPO processing can be improved through: taking into account the fraction of the fruit, minimize oil losses, operate mills under Standard Operating Procedure (SOP), promoting the quality of oil and palm kernel oil, conduct a strict supervision of fresh fruit bunch acceptance, delivery of production, sales operation as well as equipment calibration based on the schedule of maintenance, replacing damaged measurement tools, calibrating laboratory equipment, conducting process and production controls. Therefore, in this study we will develop model of crude palm oil supply chain to determine the ratio of fulfillment of cooking oil and cooking oil fabrication industry efficiency. Increasing fulfillment ratio of CPO can be done through increasing the productivity of CPO by conducting replanting in smallholder areas and reducing oil losses.

Literature review

Supply chain management: Supply chain management is a mechanism to increase total productivity of companies in the supply chain by optimizing material flow quantity, location and time (Djohar *et al*., 2013). The supply chain component includes suppliers of raw materials, palm oil producers, domestic customer, overseas customer and environment (forest) as shown in Fig. 1 (Widodo *et al*., 2010). 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 around 3,358,000 ha (50.7% of national land area). 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 small holder 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.

Today indonesia has about 23 different types of derivative products that have been produced (BAPPENAS., 2010). The potential of Indonesia's palm oil and CPO production in 2010 that has reached 20 million tons indonesia need to enhanced derivative products (MI., 2009). With this various derivative products of CPO

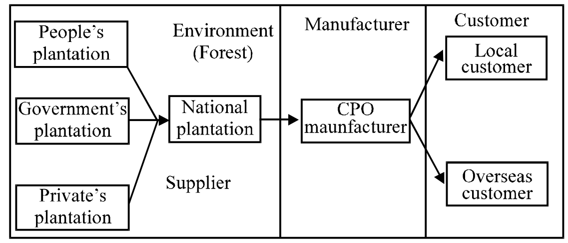

Fig. 1: Supply Chain management of crude palm oil Widodo *et al*., 2010)

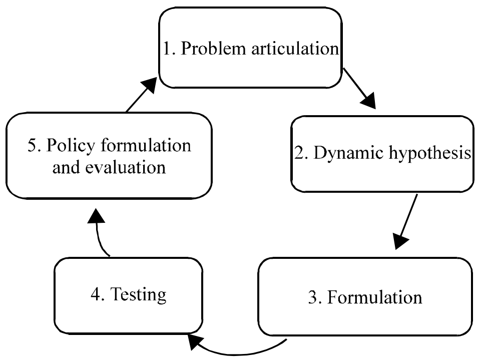

Fig. 2: Sterman's five-step In developing system dynamics model (Sterman, 2000)

processing, 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.

System dynamics: In the previous study presented modeling is a creative process in which each modeler approaches a problem differently (Sterman, 2000). This study states that the modeler gets feedback from the real world, adjusts the model and then provides additional model feedback to the real world. There are five essential steps to modeling that are characteristics of all successful modeling efforts such as depicted in Fig. 2.

Step 1: Problem articulation: In this step, we need to find the real problem, identify the key variables and concepts, determine the time horizon and characterize the problem (Sterman, 2000).

Step 2: Dynamic hypothesis: Modeler should develop a theory of how the problem arose. In this step, we need to develop causal loop diagram that explain causal links among variables and convert the causal loop diagram into flow diagram (Sterman, 2000).

Step 3; Formulation: To define system dynamics model, we should translate the system description into system dynamics variables such as level, rate and auxiliary equations (Sterman, 2000).

Step 4; Testing: The purpose of testing is comparing the simulated behavior of the model to the actual behavior of the system (Sterman, 2000).

Step 5; Policy formulation and evaluation: Once modelers have developed confidence in the structure and model behavior, we can utilize it to design and evaluate policies for improvement. The interactions of different policies must also, be considered because the real systems are highly nonlinear, the impact of combination policies is usually not the sum of their impacts alone (Sterman, 2000).

MATERIALS AND METHODS

Base model development: In this study, we demonstrate model development of cooking oil supply chain model that includes the following.

Area plantation sub model: 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 yeasr and area with uncertified seed as seen in Fig. 3. 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.

Land productivity sub model: Figure 4 shows a flow diagram of land productivity. As we can see from Fig. 4, land productivity is affected by the adequacy of fertilizer, humidity, precipitation, temperature and lighting. Based on the simulation resultss, 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.

Crude palm oil production submodel: Figure 5 shows the flow diagram of crude palm oil production. As we can see from Fig. 5, 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 Eq. 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)

Simulation results show that small holder's CPO production in 2015 was around 11,760,109 tons, government's production was around 2,240,188 tons and private production was around 16,696,148 tons.

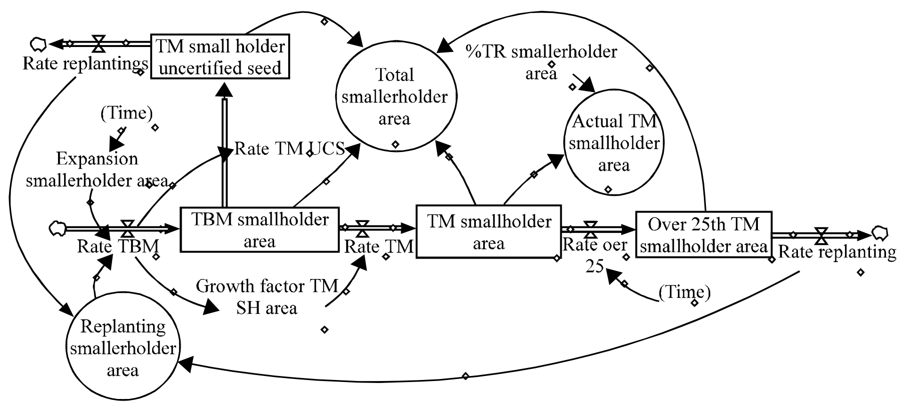

Fig. 3: Flow diagram of smallholder plantation

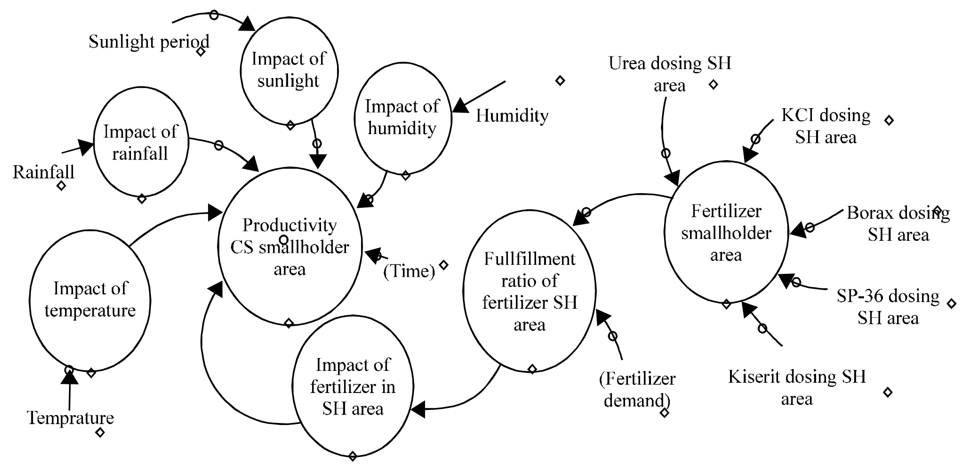

Fig. 4: Flow diagram of land productivity

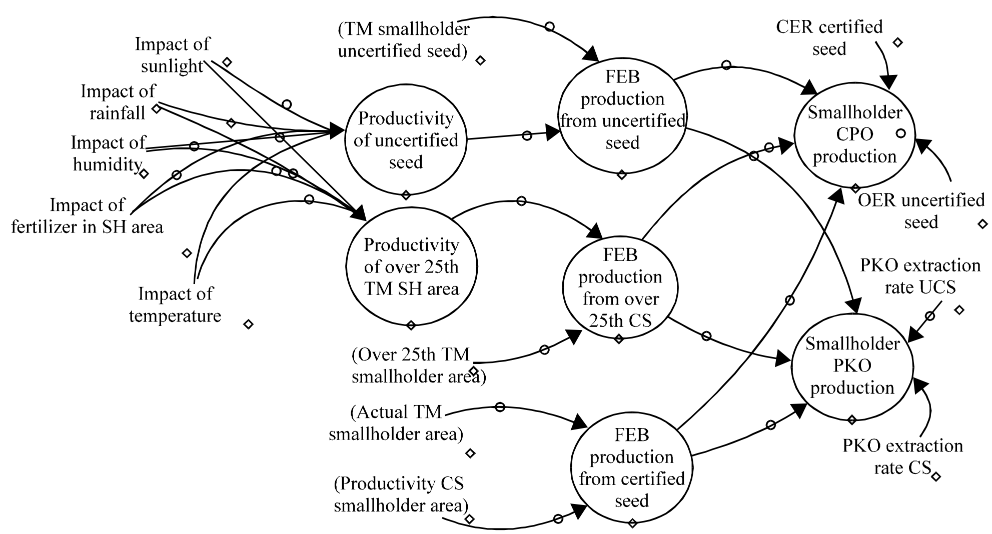

Fig. 5: Flow diagram of Crude Palm Oil (CPO) production

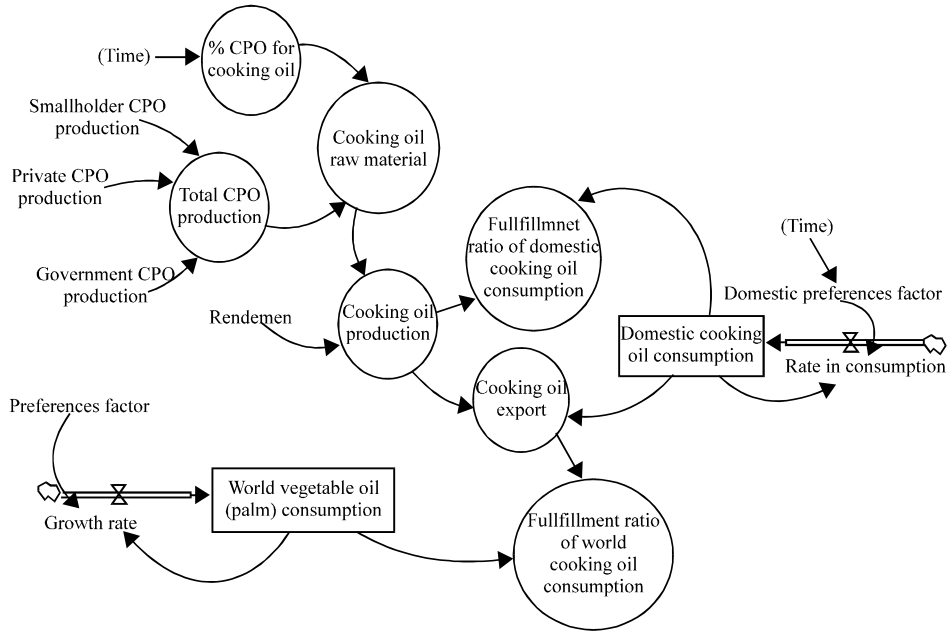

Fig. 6: Flow diagram of cooking oil production

RESULTS AND DISCUSSION

Model validation: Model validation is required to check the model validity. A model will be valid if the error rate is <5% and error variance is <30% (Barlas, 1996). Error rate and error variance are defined in Eq. 2 and 3:

$$\text{Error rate} = \frac{\left[\bar{S}-\bar{A}\right]}{\bar{A}} \quad (2)$$

Where:

$$\text{Error variance} = \frac{|Ss-Sa|}{Sa} \quad (3)$$

$\bar{S}$ = 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 2 to determine the Error rate and Error variance of land area and CPO production.

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

Cooking oil production and supply chain model: Figure 6 represents the flow diagram of cooking oil production.

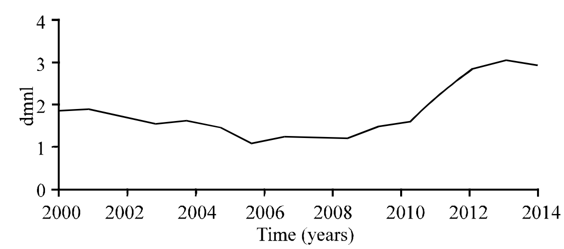

Fig. 7: The fulfillment ratio of national cooking oil

Table 1: Error rate determination

Variabels	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

Variables	SD of simulation (S_s)	SD of data (S_a)	Error variance
Land area	1163057	1116718	0.041
CPO production	2725350	3002787	0.092

As we can see from Fig. 6, cooking oil raw materials can be derived from CPO production and the percentage of CPO used for raw material of cooking oil.

In addition, this raw material will be processed into cooking oil with a rendement of around 73.8%. Fulfillment ratio depends on cooking oil production and demand. The fulfillment of cooking oil in Indonesia is >100% as seen in Fig. 7.

Scenario development to improve CPO productivity and process quality to reduce oil losses: This scenario is

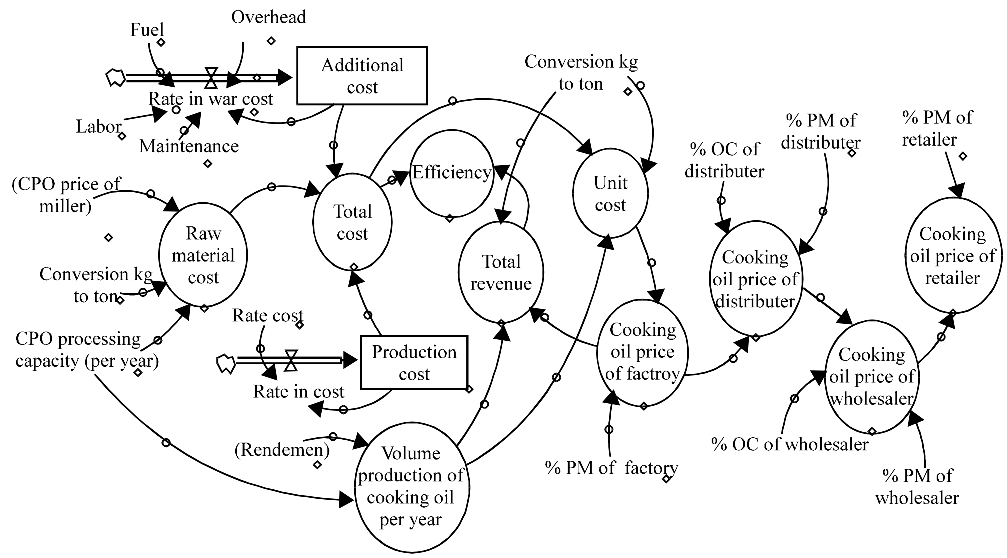

Fig. 8: Cooking oil supply chain model

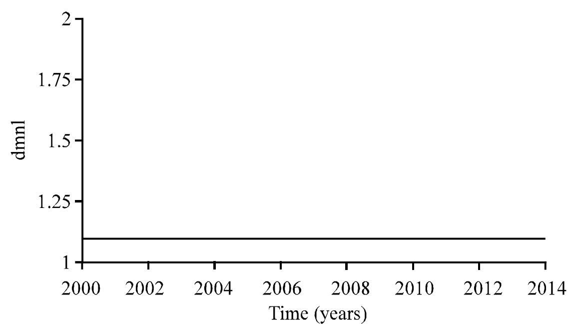

Fig. 9: The efficiency of cooking oil industry

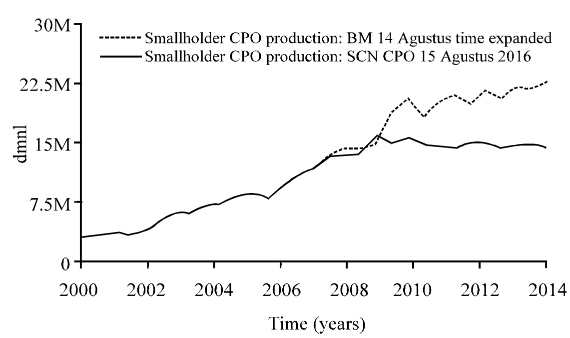

Fig. 10: Scenario development to improve smallholder CPO production

developed to improve the CPO productivity. Improvings CPO productivity can be done through balanced fertilization and the use of quality seeds quality improvement is done by increasing Oil Extraction Rate to reduce losses and the use of quality seeds.

Simulation result shows that by improving CPO productivity, smallholder CPO production would achieve 22,663,594 tons in 2030 as seen in Fig. 10.

Figure 8 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, so that in a year with an average of 25 day's 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 Fig. 9 and 10.

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. In the first phase, the area of palm oil has not produced, until the period of about 3 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 year. The total area of productive land is influenced by the area of plantation crops and the percentage of land area that suffered damage.

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. By conducting re-planting scenarios and increase the yield of OER as well as the reduction of losses, the projection of CPO production will grow with the average growth rate of around 5%/year, so that, the smallholder CPO production would achieve 22,663,594 tons in 2030.

REFERENCES

BAPPENAS., 2010. Policies and strategies to enhance value and competitiveness of Indonesian palm oil in a sustainable and equitable (Policy Paper). BAPPENAS, The Ministry of National Development Planning, Jakarta, Indonesia.

Barlas, Y., 1996. Formal aspects of model validity and validation in system dynamics. Syst. Dyn. Rev., 12: 183-210.

Djohar, S., H. Tanjung and E.R. Cahyadi, 2003. [Building a competitive advantage on CPO through supply chain management: A case study in PT Eka Dura Indonesia, Astra Agrolestari, Riau (In Indonesian)]. J. Manage. Agribusiness, 1: 20-32.

GCSL., 2009. Roadmap of CPO processing industry. General Chemical State Laboratory, Indonesia.

Herianto, D.D., 2008. Analysis of Indonesia's CPO industrial competitiveness in international markets. Master Thesis, Bogor Agricultural University, Bogor, Indonesia.

MAFW., 2015. Fifty percent of oil palm plantations owned by smallholder (farmer) need replanting. Ministry of Agriculture & Farmers Welfare, New Delhi, India.

MI., 2009. Industrial cluster development priorities: Agro-based industries. Ministry of Industry, Indonesia.

Sterman, J.D., 2000. Busyness Dynamics: Systems Thinking and Modeling for a Complex World. McGraw Hill, Irwin, ISBN: 0-07-231135-5.

Widodo, K.H., A. Abdullah and K.P.D. Arbita, 2010. [Indonesia's supply chain crude-palm-oil system by considering aspects of the economical revenue, social welfare and environment (In Indonesian)]. J. Ind. Eng., 12: 1-47.