Indonesian CPO availability analysis to support food and energy security: a system dynamic approach

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Abstract. The development of biofuels could be a solution to overcome the energy problem. One of biofuel that has the potential to be developed, namely palm oil biodiesel that is also the raw material for food. As a provider of CPO raw materials, the production of palm biodiesel could trigger competitions, from biofuels demand growth and utilization of agricultural resources. Thus, it needs to be analyzed to determine the adequacy of CPO supply to fulfill the need of food and policy recommendation which sets the development of palm oil biodiesel can be synergies with food need especially for the supply of raw material CPO. To obtain the optimal policy in the synergy between the raw material of CPO for food and energy is a need to establish some policy scenarios that allow to be applied and then chosen the best policy alternative of all scenarios. The purpose of this research were to: 1) analysis the availability of CPO to meet the needs of food and energy, 2) provide policy recommendation with regard biodiesel development of food security. The model made used system dynamic method. Several scenarios that used in the model are: 1) existing condition, 2) The scenario increase biodiesel production capacity and increase land productivity, 3) reduction scenario CPO export by 30%, 4) scenario use other raw material for biodiesel by 20%. The simulation results showed the availability of CPO raw materials would answer all needs of both food and biodiesel when there was an increase in productivity, diversification of raw materials, and also a reduction in palm oil exports. It was needed an integrated policy from upstream to downstream along with the consistency of implementation. Policy suggestions that could be considered were increased productivity through agricultural intensification, enforcement disincentive policies of CPO to exports, and development of non-CPO biodiesel raw materials and development of renewable energy.

1. Introduction

Energy is one of the critical needs in mankind life. Energy need increases in line with the increase of population, technological advances, and human activities. Majority of energy use in Indonesia currently is still using fossil fuel sources. Indonesia’s oil production reached its peak in 1977 which amounted to 1,685 thousand barrels per day and continued to decline down to 909 thousand barrels per day in 2006, or decreased at a rate of 1.83% per year. On the other hand petroleum consumption...
continues to increase at a rate of 5.04% per year. This situation made Indonesia originally as an exporter turned into an importer since 2000 with an increasing level of deficit[1].

One of the sources of energy that can be an alternative is biofuel. Biofuel is fuel from biological sources. Biofuel currently becomes an option to be used as an energy source instead of petroleum. This is because biofuel is the easiest fuel to convert into energy fuel and electricity[2]. Another advantages of the use of biofuels are renewable, environmentally friendly, biodegradable, to be able eliminating the greenhouse effect, and the assurance of raw material continuity[3].

The selection of biofuel as an alternative energy is not without risk, as the source of biofuel raw materials are plants that require land, time, seed and maintenance. In fact, most of biofuel raw materials are also a need for human food such as sugar cane, cassava, corn, palm oil, and soybean[4]. On the one hand Indonesia must develop biofuels, but on the other hand Indonesia must continue to ensure food security and production sustainability of some kinds of food commodities.

Food is a basic need that is essential for human beings that need to be met before other needs in sustaining life and living. Food security in UU No. 7/ 1996 is defined as the fulfillment of the conditions of adequate food, both in quantity and quality, safe, equitable, and affordable. If competition between food and energy needs occurs through the development of biofuels, the food security should take priority first. Therefore, the development of biofuels should be consistent with the management of Indonesian food.

The availability of food and energy in sufficient quantities is very vital for every country. Both are consumed either to meet the main needs of beings living or as an input factor in the production process. The development of biofuels based on food crops can encourage competition with efforts to comply the food. Bioenergy development requires land for planting area and the availability of water. Therefore, the development of bioenergy raises the potential threat on food security as a result of the conversion and the competition between energy and food needs to the people[5,6,7].

One of the food raw materials that can be used as a biofuel raw material is crude palm oil (CPO). Utilization of domestic CPO all this time is used as a derivative industrial raw material of CPO which consists of eighteen kinds of products divided into the food and non-food industries. The increase in fuel prices on the domestic CPO demand will provide a broad impact in the palm oil industry. CPO demand for energy will compete with CPO demand for food. That is one of the factors causes food prices and cooking oil in Indonesia soared out of control. Its impacts are the appearing of shortage and decreased supply[8]. Influence of domestic policy which sets the production of biofuels has a positive impact that biofuels product has the competitiveness in the market. To increase the production and biofuels consumption required obligation of use biofuel policy, tax exemption and subsidies[9].

Palm oil is one commodity that has strategic value because it is one of nine basic needs of Indonesia. High demand for palm oil both inside and outside the country is an indication of the importance oil palm in the nation’s economy. Palm cooking oil needs continue to increase from year to year as the increase of population, development of mills and food industry, and rising public consumption will be cooking oil to cook. The system dynamics approach is a good method to understand the behaviour of a complex system over time[10]. Some researchers developed system dynamic model in bioenergy development like to analyze the effects of government policy for stimulating biodiesel industry[11]. The purpose of this research were to ; 1) analysis the availability of CPO to meet the needs of food and energy, 2) provide policy recommendation with regard biodiesel development of food security.
2. Methodology

2.1. Framework
The population growth increases every year will lead to the increase of demand on food, energy, and land for residence and industry. Limited reserves of fuel in Indonesia caused the government began to look at the use of biofuels as an energy source. Increased food and energy requirements need to be in line with an increase in supply or production of raw materials for food and bioenergy. Sources of potential bioenergy raw materials for development is also a source of raw materials for food such as palm oil. On the other hand the amount of agricultural land is also limited. Thus bioenergy development can potentially lead to food insecurity as a result of competition of raw materials and land acquisition for the food fulfillment for community. The causal relationship among involved variable groups can be seen in figure 1.

![Causal relationship among involved variable groups](image)

**Figure 1.** Causal relationship among involved variable groups

2.2. Types and sources of data
The data used in this study were primary and secondary data. Primary data was collected through interviews and discussions with respondents related to the research, which consisted of industry associations, the government (Ministry of Energy and Mineral Resources, Ministry of Agriculture, Ministry of Trade, and Ministry of Industry), and research institute. Meanwhile secondary data was time series data. Secondary data in the study were collected from various sources such as statistics of Indonesia report and also documents and research papers from various agencies associated with the research. Time period simulation that has been to be performed is 2015 – 2030.

2.3. Data analysis methods
System is the collection of elements or sub-system that interact with each other, work together to achieve a certain goal[12]. System dynamic is related to the behavior of system that changes according to the time, with the aim to explain and understand the feedback affect behavior of system, then designs the structure of the information feedback and control policies appropriate, through simulation
and optimization of the system by using qualitative and quantitative methods. Feedback from a particular pattern of the dynamic model is one of the core of a system dynamic [13]. This methodology is focused on making policy and how that policy determines the behavior of the problem issues that can be modeled by the system dynamic [14].

Stage in this dynamic system approach begin with understanding the system, identification of problems, conceptualization system, the formulation of model, simulation and model validation, policy analysis and implementation models [10]. This process of dynamic system approach can be seen in figure 2.

Figure 2. Stage of system dynamic approach

Basic equation of mathematical system dynamic is:

\[
\frac{d}{dt} x(t) = f(x, p)
\]

where “x” is a vector stock, “p” is parameter, and “f” is a nonlinear factor function [14]

2.4. Validation
Model validation was carried out to assess whether the model was set up to represent the system in the real world so that it could be concluded convincingly [15]. Error measurement method used in this study was RMSPE (Root Mean Square Percent Error) or an error percentage of square root average, which was calculated by the formula:

\[
\text{RMSPE} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{S_i - A_i}{A_i} \right)^2}
\]

By \(A_i\) as an actual value, \(S_i\) as the computer simulation value, \(n\) as a data amount reflected the length (time/data) collected.
3. Results and discussion

3.1 Model identification
Model identification is a chain of relationships between needs of system actors with existing problems to meet those needs. The linkage is illustrated in the causal loop diagram in figure 3. Causal loop diagram is the disclosure of the incident causal relationship (causal relationship) into the language of a particular image. The picture language is an arrow interlocking, thus forming a simple diagram, where the upper arrow reveals the causes and arrowhead reveals as a result[16].

![Causal loop diagram](image)

**Figure 3.** Causal loop diagram

The simulation result is expected to generate projections CPO sufficient material to meet the need of food (cooking oil and margarine) and biodiesel need (mandatory target).

3.2 Model development
Development of bioenergy development policy modelin taking food security was composed of four sub-systems, namely: (1) land and plantation subsystem, (2) CPO raw material subsystem, (3) food need subsystem, and (4) biodiesel need subsystem.

Based on the causal diagram that had been prepared, then was prepared a flowchart (stock flow diagram) to describe the model in more detail due to the influence of each time and the relationship between variables. Thus there would be variable indicated accumulation results in a system called a level, and variable as system activity and influenced level called rate. After setting up the model, then was devised a mathematical formulation of the model could be simulated.
3.3 Model Assumptions
Some of the assumptions used in this modeling were:

1. The need for CPO were calculated based on food raw material needs, CPO exports, and biodiesel raw material demand. Food needs were calculated based on the needs of cooking oil and margarine.
2. CPO provision was only calculated based on the number of CPO production in the country. CPO import was negligible.
3. The rate of export CPO growth was 10.85% per year.
4. The rate of oil export growth was 13.02% per year.
5. The rate of biodiesel production growth was 24.43% per year and the value of CPO conversion into biodiesel was 97%.
6. The rate of biodiesel export growth was 10% per year.
7. The rate of cooking oil production growth rate was 12.71% per year.
8. The rate of solar needs growth was 32.70%.
9. The needs of margarine and cooking oil per capita were respectively 0.065 kg per year and 14.21 kg per year, with CPO conversion values into margarine and cooking oil were 6.67 tonnes of CPO/tons of margarine and 1.37 tonnes of CPO/tons of cooking oil.
10. The rate of Indonesia's population growth was 1.49% per year.
11. Simulation analysis period was limited to period 2015 to 2030.

3.4 Model validation
To get the correct conclusion based on the requirements that had been established was necessary to validate the model that had been made[17]. The test result showed that RMSPE value for palm plantation land area variable was 6.3763% and for CPO production value was 7.5875 (figure 4 and figure 5). This value was lower than the required maximum value limit of 10%. Deviation limits of both variables showed that this model was able to simulate the changes occurred actually on the field so that the model could be declared valid.

![Figure 4. Actual and simulation results data graph for palm oil plantation area](image-url)
3.5 Policy scenario and simulation results

In order to formulate policy of CPO raw material supply for food and energy was needed various simulations to determine the appropriate alternative policy options. Several scenarios used in this study were:

1. Basic scenario. In this scenario the system condition was kept as the condition of the present day.
2. The increase of biodiesel production capacity and land productivity scenario. At this scenario was assumed an increase in biodiesel production capacity so that biodiesel production capacity could meet the achievement of biodiesel mandatory target. Besides, land productivity also was increased gradually until it reached 4 tons/ha.
3. Reduction of 30% in CPO export scenario. At this scenario was used the previous scenario and added with a reduction in CPO exports amounted to 30% of the previous that was allocated to meet domestic demand.
4. The 20% use of other raw material for biodiesel scenario. On this scenario, the previous scenario was added with the assumption that the non-palm oil raw material biodiesel contribution was 20% to meet the mandatory target.

In 2015, the Ministry of Energy and Mineral Resources issued Regulation of Minister of Energy and Mineral Resources No. 12/2015 as a refinement of Regulation of Minister of Energy and Mineral Resources No. 32/2008 concerning the provision, utilization, and administration of biofuel as the other fuel. One of its content is to establish the obligation of a biodiesel minimum use as a fuel mixture for use in household, PSO and non-PSO transportation, industrial and commercial, and power plant sectors in stages starting in 2015 until 2025 as shown in Table 1.

Figure 5. Actual and simulation results data graph for CPO production
| Sector                          | April 2015 | January 2016 | January 2020 | January 2025 | Description               |
|--------------------------------|------------|--------------|--------------|--------------|---------------------------|
| Household                      | -          | -            | -            | -            | Not specified             |
| Micro industry, fisheries      | 15%        | 20%          | 30%          | 30%          | nowadays                  |
| transportation and General     |            |              |              |              | On total needs            |
| Non-PSO Transportation         | 15%        | 20%          | 30%          | 30%          | On total needs            |
| Industrial dan commercial      | 15%        | 20%          | 30%          | 30%          | On total needs            |
| Power plants                   | 25%        | 30%          | 30%          | 30%          | On total needs            |

Source: Regulation of Minister of Energy and Mineral Resources No. 12/2015

Table 1. The obligation of minimal utilization of biodiesel to the total need

Every year oil palm plantation area always increase with a total land area in 2013 was estimated to reached approximately 10,010,824 hectares. Indonesia's palm oil production also continues to increase every year. In 1990 Indonesia's palm oil production reached 2,412,612 tons and in 2013 increased to 27,746,125 tonnes[18].

Biodiesel industry in Indonesia is basically a new industry (which began around 2006) that are vulnerable to external shocks. To reach the mature stage of industry, is needed long process and time, and also often require the government intervention. Some of problems faced by biodiesel businesses/producers in Indonesia are price fluctuation of CPO raw materials, fuel subsidy policy, certainty of domestic market, production capacity, and availability of land [19]. According to the Ministry of Energy and Mineral Resources, nowadays there are about 25 companies that have licenses to produce biodiesel with a total of installed capacity is 5.67 million kiloliters. All of biodiesel industries in Indonesia use palm oil as a raw material.

As the population increases, also the industries and motor vehicles increases in Indonesia, the fuel needs will also increase. The existence of biofuel mandatory policy will automatically increase the domestic biodiesel needs. Thus, Indonesia should increase biodiesel production to meet the mandatory target.

Cooking oil has a strategic role in the national economy because it includes as one of the nine basic material needs that are important to the community. With the increasing number of Indonesian population, the consumption of cooking oil is likely to increase from year to year. Based on data [20], the amount of cooking oil consumption of Indonesian community in 2008 amounted to 9.6 kg/capita/year, and in 2011 increased to 10.7 kg/capita/year.

The simulation results of system dynamic model on basic scenario as seen in figure 6 and figure 7 showed that CPO production and food needs was continued to increase during simulation period. This increase occurred because the oil palm plantation area was expected to continue increasing every year due to demand increase for CPO raw material, both for domestic consumption and export.
In 2014 Indonesia’s CPO production was 29 million tons and was expected that in 2030 CPO production will increase almost 3x more for about 80 million tonnes. As the growth of Indonesia’s population, it is estimated that food need to meet domestic need is also expected to continue the increase every year. The simulation result (figure 6 and figure 7) showed that in 2030 will be required CPO raw material of 5.323.274 tons only to meet domestic food consumption (cooking oil and margarine).

The simulation result for energy need, particularly diesel, was also showed an increase during the simulation (figure 8). In 2014 diesel need reached 35.382.510 kiloliters and will increase to 56.305.728 kiloliters in 2030. Assuming that the mandatory target of biodiesel will be successfully implemented, the biodiesel need prediction in 2030 will be 16.545.761 kiloliters. On the other hand, production capacity of biodiesel industry currently was only about 6 million kiloliters. Thus the biodiesel need in the future will not be met with current production capacity, so that is necessary to increase production capacity. In proportion, it showed that the percentage of CPO demand for raw materials of biodiesel in order to meet mandatory target was much larger than CPO need portion to meet domestic food need. CPO demand portion for domestic biodiesel raw material in 2030 was expected to reach approximately
75%, while the portion of CPO need to meet domestic food need was estimated only about 25% (figure 9).

Figure 9. Simulation results for food needs and biodiesel needs for domestic

Figure 10 shows a CPO availability which is the difference between CPO production, CPO need for food, biodiesel, oleochemical and export. The simulation results of basic scenario and scenario 1 and 2 showed that at the beginning, CPO production was still able to meet their food needs, CPO export, and biodiesel need until 2025. After 2025, the availability of CPO showed a tendency to decrease with the increasing deficit rate and was estimated that CPO raw material supply would only meet all needs until 2029. It was because the estimate that in 2025 land availability for oil palm development would be reduced because of competition with residence needs, industry, and the development of other agricultural commodities. Besides, the moratorium policy on Indonesia’s forest to converse into plantations also affected the rate of oil palm plantations. In scenario 3, simulation result of this scenario showed that during time simulation, biodiesel mandatory target could be achieved by not causing a shortage in CPO raw material for food needs.

Figure 10. CPO availability simulation results
Figure 11 and figure 12 showed the total portion of CPO for food and energy needs, both for domestic consumption and export, to meet the needs of derivative products. The simulation results of the basic scenario and scenario 1, 2, and 3 showed that total of CPO need for food was far greater than total of CPO need for biodiesel. CPO portion of food ranged between 40-60%, while the CPO portion of biodiesel ranged between 10-30%, and the remaining was used for CPO exports in raw form. CPO for biodiesel portion tended to increase until 2020 due to a mandatory increase in mixture of biodiesel and increased diesel from 15% to 30%. After 2020, because there was no percentage increase of biodiesel mixture with diesel, so that CPO portion from biodiesel tended to decrease. Similarly, the CPO for food portions tended to decrease until 2020 and then increased after 2020.
4. Conclusions

Based on simulation results, it can be seen that the created model had been able to describe the increase in demand for CPO raw materials due to biodiesel mandatory target that might affect the availability of CPO raw materials to meet food needs. Simulation result shows that oil palm plantation area will continue to increase to certain extent, thus CPO production increases throughout the year. The policy of mandatory biodiesel can increase CPO demand for domestic food (cooking oil and margarine). CPO surplus simulation result for scenario 1 and 2 shows that in 2015, there is sufficient material CPO to fulfill all needs for food, energy and also export, even there is a surplus with surplus increasing tendency until 2025. After 2025, the availability of CPO showed a tendency to decrease with the increasing deficit rate and was estimated that CPO raw material supply would only meet all needs until 2029. In scenario 3, simulation result of this scenario showed that during time simulation, biodiesel mandatory target could be achieved by not causing a shortage in CPO raw material for food needs. Availability of CPO raw materials would meet all needs, both of food and biodiesel, when there was an increase in productivity, diversification of raw materials, and also a reduction in palm oil exports. It was needed an integrated policy from upstream to downstream along with the consistency of implementation. Policy suggestions that could be considered were increased productivity through agricultural intensification, enforcement disincentive policies of CPO to exports, and development of non-CPO biodiesel raw materials and development of renewable energy.

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