

Indonesia's Oil Palm Bioenergy Sustainability Assessment System using Indonesian Bioenergy Sustainability Indicators (IBSI)

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ABSTRACT

Palm oil has potential to produce renewable energy bioenergy or often called bioenergy. Bioenergy from palm oil is priority government to make sustainable industry. Based on literature a basic principle of sustainability are: 1) Social, 2) Economic & 3) Environment. This research was conducted in Indonesia, where based on several palm oil company in Indonesia.

The main purpose of the research is obtain system of bioenergy sustainability assessment in Indonesia which can be reference for sustainability level of bioenergy from palm oil. The intermediate objective to achieve the main objective are: 1) Identification of the influence indicators to realize the sustainability of palm oil bioenergy, 2) Design a model for assessing the sustainability of palm oil bioenergy in Indonesia, 3) Analyze the level of sustainability of bioenergy in Indonesia with model system was already built.

The methods used in this research to asses sustainability of bioenergy in Indonesia is Fuzzy Inference System (FIS). The result showed the level of oil palm bioenergy sustainability has score 61.7 for environment indicator, 50.1 for economic indicator, and 50.9 for social indicator. Overall, the level of bioenergy sustainability is 61.7, it means the sustainability level in Indonesia quite sustainable with confidence level is 80.6%, most sustainable with confidence level is 0%, and unsustainable with confidence 19.4%.

Keywords— Bioenergy, Palm Oil, Sustainability, Fuzzy Inference System

million hectares with the result of production around 30.94 million tons. The Palm Oil's production and area are increased around 10.9 million hectares with 29,344 million tons for the yield of production [1]. The main production from Palm oil are Crude Palm oil and Kernel Palm Oil. From these main results, it can be produce as a non-food. Those are fatty acid products, fatty alcohol, stearin, glycerin, biodiesel, bioavtur, biosolar, etc. In the oil palm industry, several types of waste are produced, those are oil palm empty bunches (TKS), oil palm shells (CKS), palm fibers, oil palm trunks (BKS), palm oil leaves (DKS), liquid waste (Palm Oil Effluent or POME). This waste product has the prospect of getting another plus value, for example as a bioenergy raw materials. Bioenergy products are produced from oil palm biomass include biodiesel, biogas and biosolid [2]. According to [3] that the basic principle of sustainable development that underlies all of them is the integration of environmental, social, and economic into all aspects of making decision. Similar with the research conducted by [4], [5], [6], [7], [8] and [9] that sustainability must be integrated with environmental, economic and social aspects.

Many international forums such as the Global Bioenergy Partnership (GBEP), Intelligent Energy Europe (IEE), Roundtable on Sustainable Biomaterials (RSB). Based on the Indonesian Bioenergy Sustainability Indicator, that already formulated by the Palm Oil Plantation Fund Management Agency (BPDPKS) by conducting a series of FGD activities (forum group discussion), 10 sustainability indicators were most suitable for the sustainable development of the palm bioenergy industry in Indonesia.

Some of studies are done with using decision support fuzzy for selection of potential agricultural commodities as energy raw material [10]. Meanwhile, [11] have used the Fuzzy Inference System (FIS) method to assess the implementation of green management in several agro-industries viewed from the use of resources, production processes, environmental impacts and management internal policies.

I. INTRODUCTION

Bioenergy is one of many newest energy that can developed and mass-produced to fulfill world's energy needs. According by Food and Agriculture Organization of the United Nations (FAO), bio energy is defined as energy that results from biofuels which consist of electricity, heat and various transportation fuels.

Indonesia has potential to produce bio energy from agricultural sector which is palm oil. Palm oil is a commodity which has many benefits in every parts of its plants. In 2015, oil palm area in Indonesia reached 11.4

Table 1: Sustainability Bioenergy Palm Oil in Indonesia [12]

Sustainability Criterias	Number	Indicators
Environment	1	Life –cycle GHG Emissions
	2	Waste management and cleaner production (soil, air, and water quality & efficiency)
Social	3	Impact of change in income
	4	Jobs in the bioenergy sector
	5	Bioenergy used to expand access modern energy service
Economic	6	Productivity
	7	Net energy balance
	8	Gross value added
	9	Energy diversity
	10	Infrastructure and logistics for distribution of bioenergy

The main objective of this study is to measure the level of sustainability of palm oil bioenergy in Indonesia with several stages including: (1) Identifying the parameters that influence each indicator in the realization of increasing sustainability of palm oil bioenergy in Indonesia, (2) Designing a sustainability assessment system palm oil bioenergy using the fuzzy inference system method, (3) Analyzing the level of sustainability of palm oil bioenergy with a model of the designed palm oil bioenergy assessment system in Indonesia.

II. METHODOLOGY

This research is done by taking samples of testing data in the North Sumatra and Riau provincial provinces that being done by previous research conducted by the GBEP (Global Bioenergy Partnership) forum which was included in the patronage of the FAO(Food and Agriculture Organization) in 2012. Whereas, the data to build a sustainability valuation system from palm oil bioenergy in Indonesia, it was conducted in November 2017 - March 2018 using survey and interview methods for 10 correspondents consisting of experts, lecturers and researchers in the fields of industry, bioenergy and environment. Secondary data is also needed to support in design sustainability valuation system of palm

oil bioenergy in Indonesia which consists of statistical data, journals, and research reports related to this research.

The evaluation for the parameters of each indicator in this study is done by collecting secondary data that can present the territory of Indonesia. In design a bioenergy palm oil sustainability assessment system for aggregation, the Fuzzy Inference System (FIS) method is used.

In the method of assessment the sustainability of palm oil bioenergy in Indonesia requires the criteria and index that used to determine the sustainability of the bioenergy industry from oil palm in Indonesia. The determination of criteria for this research is sought based on three aspects of standard continuity, namely; economic, social and environmental. In these 3 aspects, each aspect will have several indicators that will be assessed based on the parameters of each indicator.

In the method of assessing the sustainability of palm oil bioenergy in Indonesia, it requires criteria and index that are used to determine whether the bioenergy industry from oil palm in Indonesia is sustain or not. The determination of criteria for this research is sought based on three aspects of standard continuity, namely; economic, social and environmental. In these 3 aspects, each aspect will have several criteria to be assessed. Following is the dependency diagram of the FIS data processing method (Figure 1).

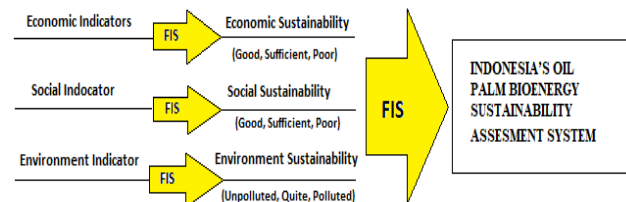


Fig. 1: Dependency Diagram of Data Processing Method with FIS

These criteria are indicators or factors for sustainability standardization referring to the Indonesian Bioenergy Sustainability Indicators (IBSI). In assessing the sustainability of Indonesia's palm bioenergy, the obtained data will be processed using MATLAB with several stages, along with the stages in processing the data:

a) Data Normalization

Data normalization is the initial process is done for scaling the input values in order to obtain an input values into a certain range. In this process scaling in the form of percentage is 0 - 100%. The input data is normalized by entering the data value into the following equation:

$$\hat{x} = \frac{x - x_{min}}{x_{max} - x_{min}} * 100\%$$

b) Fuzzification

The next step is the fuzzification process which is the first step in the fuzzy inference system method. This process is the process of mapping a crisp value into a fuzzy set or its called the formation of a membership function. For economic sustainability variables are divided into three classes, those are good (BA), sufficient (S), bad (BU). The following is an equation of the degree of membership from economic sustainability.

$$\mu_{BA}[x=E] \begin{cases} 0; x > 50 \\ \frac{50-x}{50-0}; 0 \leq x \leq 50 \end{cases}$$

$$\mu_S[x=E] \begin{cases} 0; 0 > x > 100 \\ \frac{x-0}{50-0}; 0 \leq x \leq 50 \\ \frac{100-x}{100-50}; 50 < x < 100 \end{cases}$$

$$\mu_{BU}[x=E] \begin{cases} 0; x < 50 \\ \frac{x-50}{100-50}; 50 \leq x \leq 100 \end{cases}$$

While for social sustainability variables are divided into three classes, those are good (BA), medium (S), bad (BU). The following is an equation of the degree of membership and social sustainability.

$$\mu_{BA}[x=S] \begin{cases} 0; x > 50 \\ \frac{50-x}{50-0}; 0 \leq x \leq 50 \end{cases}$$

$$\mu_S[x=S] \begin{cases} 0; 0 > x > 100 \\ \frac{x-0}{50-0}; 0 \leq x \leq 50 \\ \frac{100-x}{100-50}; 50 < x < 100 \end{cases}$$

$$\mu_{BU}[x=S] \begin{cases} 0; x < 50 \\ \frac{x-50}{100-50}; 50 \leq x \leq 100 \end{cases}$$

For environmental sustainability variables are also divided into three classes namely very healthy (SS), healthy (S), and polluted (TC). In the below is the equation of the degree of membership from environmental sustainability.

$$\mu_{SS}[x=L] \begin{cases} 0; x > 50 \\ \frac{50-x}{50-0}; 0 \leq x \leq 50 \end{cases}$$

$$\mu_S[x=L] \begin{cases} 0; 0 > x > 100 \\ \frac{x-0}{50-0}; 0 \leq x \leq 50 \\ \frac{100-x}{100-50}; 50 < x < 100 \end{cases}$$

$$\mu_{TC}[x=L] \begin{cases} 0; x < 50 \\ \frac{x-50}{100-50}; 50 \leq x \leq 100 \end{cases}$$

For the results of aggregation of social, economic and environmental parameters, that will be done with classifying the three class, those are sustainable, quite sustainable, not sustainable. This is the equation in the degree of membership the sustainability assessment of palm oil bioenergy in Indonesia.

$$\mu_S[x=F] \begin{cases} 0; x > 50 \\ \frac{50-x}{50-0}; 0 \leq x \leq 50 \end{cases}$$

$$\mu_{CS}[x=F] \begin{cases} 0; 0 > x > 100 \\ \frac{x-0}{50-0}; 0 \leq x \leq 50 \\ \frac{100-x}{100-50}; 50 < x < 100 \end{cases}$$

$$\mu_{TS}[x=F] \begin{cases} 0; x < 50 \\ \frac{x-50}{100-50}; 50 \leq x \leq 100 \end{cases}$$

c) Rules Base

The base of this rule depends on the number of input variables number. This variable will form the basis of the rule with the formula 3ⁿ with n is the number of input variables, then we will get 27 rules.

Table 2: Example of Rules Base Assessment Valuation Sustainability Bioenergy Palm Oil

No	Input Variable			Output Variable
	Environment	Social	Economic	
1	Very Healthy	Good	Good	Very Sustainable
2	Very Healthy	Good	Medium	Sustainable
3	Very Healthy	Good	Bad	Unsustainable
4	Very Healthy	Medium	Good	Sustainable
5	Very Healthy	Medium	Medium	Sustainable
6	Very Healthy	Medium	Bad	Unsustainable
7	Very Healthy	Bad	Good	Unsustainable
8	Very Healthy	Bad	Medium	Unsustainable
9	Very Healthy	Bad	Bad	Unsustainable

d) Defuzzification

The defuzzification process is the process of mapping the magnitude of a fuzzy set to a crisp form because this system is set with real quantities rather than fuzzy quantities, this defuzzification process uses the

centroid method. To map the magnitude of the fuzzy set using the centroid method, the moment divided by the area.

$$z^* = \frac{\int z \cdot \mu(z) dz}{\int \mu(z) dz}$$

$$z = 61.7$$

e) Verification and Validation of the Test Results

At this stage it needs to be done which is useful to see and measure the accuracy of the results . Validation is done using the MAPE method (Mean Absolute Percentage Error). If the value in MAPE is less than 25%, the results of the estimation can be received very satisfactorily [13].

$$MAPE = \sum_{i=1}^p \frac{|aktual - estimasi|}{p} \times 100\%$$

$$MAPE = 16.4\%$$

III. RESULT AND DISCUSSIONS

The result for economic sustainability measured by several variables that affect economic sustainability, namely the level of production costs, productivity, gross value added, net energy ratio, and mix of other energy sources. This variable assessment is done by aggregation of the five variables using the fuzzy inference system method. This variable is divided into 3 fuzzy sets which are good (BA), sufficient (C), and bad(BU). This set uses triangle linear curve.

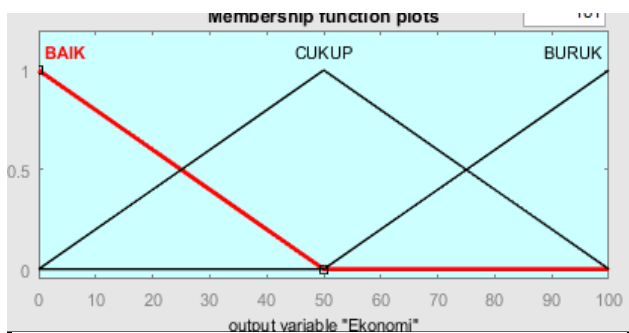


Fig. 2 Variable Membership Function Level of Economic Sustainability

Based of the obtained data, the number of biodiesel production in Indonesia in 2012 - 2017 are around 2.859,000 KL / year with the highest production in 2014 at 3,961,000 KL / year [14]. The ratio of Net Energy Balance that measured in one of the biodiesel manufactory in North Sumatra is 1: 5.35 [15]. Moreover, the gross added value is seen from the biodiesel's contribution in increasing national GDP which shows around 0.20% of national GDP in 2015-2017 [14]. The equality level of conventional energy use, renewable energy, and bioenergy in 2014-2016 is around

0.287 (Herfindahl Index). Meanwhile, the estimated production costs of biodiesel is around 687 USD / Ton CPO [15].

Table 2: Measurement Results and Calculation of Economic Sustainability

	Economic Variable Input					Economic Sustainability	
	Cost of Production	Biodiesel Productivity	Net energy ratio	GVA	Energy Diversity		
Meas	687 USD/T ON	2859 kl/th	5.35	\$0.20	0.287	Score	Class
Normalize	18.84	28.5	48.15	50	28.7	50.1	Medium

From table 2, it can be seen that the economic criteria get a score about 50.1 which it is in the sufficient category with a 99.8 % of fulfillment rate and a bad category with a fulfillment rate, 0.2%.

The result for economic sustainability measured by several variables that affect social sustainability, namely change in income, jobs in the bioenergy sector, and bioenergy mixture. Assessment of this variable is done by aggregation of the three variables using the fuzzy inference system method. This variable is divided into 3 fuzzy sets which are good (BA), medium (S), and bad (BU). This set uses a triangle linear curve.

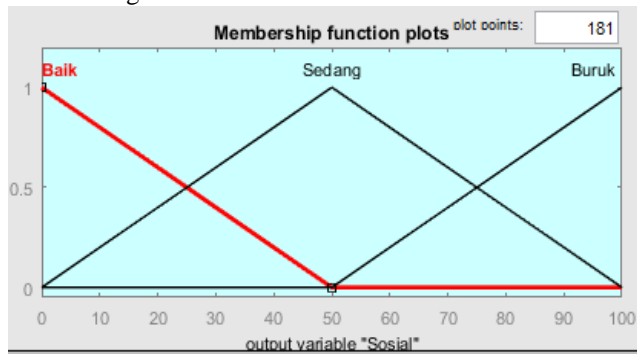


Fig. 3: Variable Membership Function of Social Sustainability Level

In 2012, Many of the worker on oil palm plantations in North Sumatra Province only received a basic salary around Rp. 1,186,797 which it can be said at a low level because it is still below the 2012 UMR, which is Rp. 1,200,000, while for workers in palm oil manufactory and bioenergy, their salary is Rp. 1,843,658 which it is above the UMR of North Sumatra in 2012. For the absorption capacity of workers in 2012-2016 there were around 220,547 worker. While equation using the bioenergy in the

industrial sector, households, transportation in 2015-2016 was around 0.38 using herfindahl index.

Table 3 Measurement Result and Calculation of Economic Sustainability

	Social Variable Input			Economic sustainability	
	Change in Income	Jobs in bioenergy sector	Bioenergy used to expand access modern energy service		
Meas	Rp. 1.515.227	0.00000368	0.38	Score	Class
Normalisasi	18.5	21.5	38	50.9	Medium

From these data, the obtained score for social criteria are 50.9 which in the medium category with a fulfillment rate of 98.2% and a bad category with a fulfillment rate 1.8%.

The output value of sustainability in environment aspects that consist of several parameters, those are the level of air pollution produced from factory equipment, toxic gases produced from biodiesel, the level of water pollution around the bioenergy industry from palm oil and the level of greenhouse gas emissions. Assessment of this variable is done by aggregation of the three variables using the fuzzy inference system method. This variable is divided into 3 fuzzy sets which are very healthy (SS), healthy (S), and polluted (TC). This set uses a triangle linear curve.

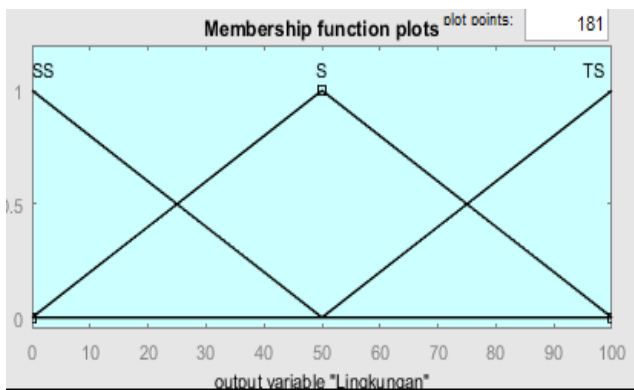


Fig. 3: Variable Membership Functions Level of Environmental Sustainability

In 2012, in large scale companies or small scale entrepreneurs, without the Land used change or with Land use change and using methane capture or without using methane capture it did not affect environmental criteria with

a score of 83.6 which was categorized as polluted triggered by SO2 exhaust gas amounting to 0.73 mg / MJ in the biodiesel combustion process which exceeds the threshold value of 0.47 mg / MJ [8], but compared with the Land used change and the absence of methane capture will contribute more to environmental pollution with produced greenhouse gas emissions. From the table 4, the level of environmental sustainability is included in the polluted category with a fulfillment rate of 67.2% and also into the category of health with a fulfillment rate of 32.8%.

Table 4: Results of Measurement and Calculation of Environmental Sustainability

	Social Variable Input				Economic Sustainability	
	Pollution from machine	Water Quality	GHG	Air Quality		
Meas	50	46.6	58.68	83.3	Score	Class
Normalisasi	50	46.6	58.68	83.3	83.6	Polluted

This variable is the value of the output of sustainable palm oil bioenergy in Indonesia by aggregating from the results of environmental, economic and social. This variable is divided into 3 fuzzy sets, which are sustainable (S), quite sustainable (CS), and not sustainable (TS). This set uses a triangle linear curve.

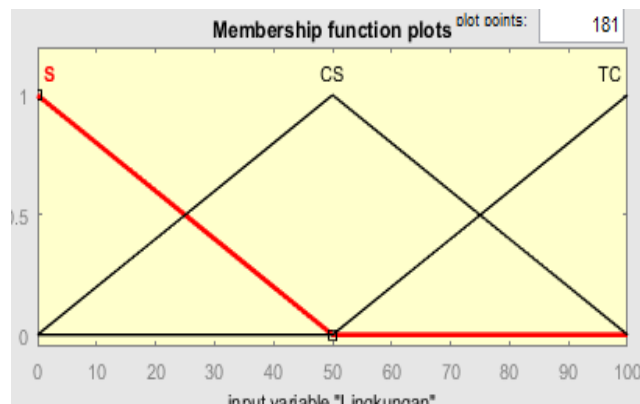


Fig. 3: Variable Membership Functions of Palm Oil Bioenergy Sustainability in Indonesia

From table 5, the score on the assessment of palm oil bioenergy sustainability in Indonesia shows 61.7 which it means that the sustainability of palm oil bioenergy in Indonesia is in enough sustainable category with a confidence level 80.6% and a non-sustainable category with a confidence level 19.4%.

Table 5: Results of Measurement and Calculation of Environmental Sustainability

	Variable Sustainability Input			Sustainability Level	
	Economic	Social	Environment		
Meas	50.1	50.9	61.7	Score	Class
Normalize	50.1	50.9	61.7	61.7	Medium

IV. CONCLUSIONS

Based on the results of the study it can be concluded that the level of sustainability of palm oil bioenergy in Indonesia is included in a fairly sustainable category with a confidence level of 80.6% and a non-sustainable category with a confidence level of 19.4% with a score of 61.7 and the percentage error value is 16.4%. The availability of data is an obstacle in this study, it is suggested that an assessment of the sustainability of palm oil bioenergy in Indonesia is necessary to complete and observe several bioenergy industries to complete for the assessment data that very complex and and sustainability assessment of Palm Oil in Indonesia that must to focused on one only company

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