GIS-based Sustainability Assessment for Palm Oil Industry

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Abstract **– The palm oil industry has its own issues, and one of them is related to sustainability issues. This paper aims to analyze and visualize the sustainability performance of the palm oil industry with Geographic Information System (GIS). The sustainability of the palm oil industry has three main dimensions, which are Economic, Social and Environmental. In this paper, 7 sustainability indicators were used in each of these dimensions. The results provide the sustainability performance measurement of the palm oil industry on several locations in Sumatra & Borneo islands, and have been visualized using the QGIS application.**

Keywords **– sustainability performance, palm oil industry, geographical information system.**

1. Introduction

Palm oil is one of the raw materials that are required to produce variety of products that are commonly consumed by the public. That includes food, cosmetics, perfume, to vehicle fuel. Palm oil is considered to be more productive, when planted in same field size, compared to other commodities such as soybean and sunflower oil [1].

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In Indonesia, the oil palm industry continues to grow followed by the increase of the land size which is prepared for oil palm plantations. In 2019, the area size of oil palm plantations in Indonesia was 14,46 Million Ha and 14,59 Million Ha in 2020. In total, 26 provinces in Indonesia have oil palm plantations with Sumatra Island being the largest oil palm plantation in Indonesia at 7,663,246 Ha and followed by Borneo Island with a plantation area of 5,990,789 Ha [2].

In its development process, there are various issues faced by this industry, especially environmental issues. Some of the environmental issues faced by the palm oil industry are the reduction of natural forests area and the conversion of forest functions from natural into man-made plantation which are the cause of the reduction of wildlife, greenhouse gas emissions, and other issues such as social issues around the palm oil industry. The increasing demand for biofuels produced from palm oil in the European market also raises issues related to the negative impacts of oil palm production [1], [3].

Along with this information and issues, the palm oil industry in Indonesia is trying to make improvement by implementing various sustainability standards to resolve emerging issues. In this case, the palm oil industry in Indonesia refers to several standard criteria in terms of sustainability, which are the Roundtable on Sustainable Palm Oil (RSPO) and Indonesian Sustainable Palm Oil (ISPO). The RSPO is aimed to minimize the negative impact of the palm oil industry on the environment or communities around oil palm production area by focusing on 3 structures: prosperity, society and the planet, along with a total of 7 principles and 40 criteria in it [4]. On the other hand, ISPO has the same goals as the RSPO in terms of sustainable palm oil industry with the principles and criteria written in Articles 3 & 4 of the Regulation of the Minister of Agriculture (Permentan) RI No. 38 of 2020. ISPO has 7 principles & 30 criteria for plantation companies and 5 principles and 13 criteria for Planters [5].

Sustainability means sufficient resources for current needs without disturbing the needs of future generations [6]. Specifically, sustainability is a condition of balance, resilience and engagement that

allows humans to meet their needs without exceeding the capacity of existing ecosystems, where the ecosystem will continue to regenerate to provide what is needed for humans without reducing biodiversity [7]. The United Nations (UN) has targeted the overall implementation of sustainable development goals (SDGs) by 2030 and this development has been implemented in various areas, such as the sustainability of a country or region, industrial development, companies, and cities [6], [8]. Based on the various issues of the palm oil industry that have been written before and referring to the idea of sustainability, this paper is aimed to analyze the sustainability of the palm oil industry, started by determining the dimensions and indicators of the industry. Then, the analysis will be conducted and the results will be visualized through a Geographic Information System (GIS), based on the dimensions and indicators performance value.

There are several advantages of using GIS. In terms of landslide disaster research by [9], GIS can help analyze various data such as geological data, soil elevation, rainfall, vegetation, land use and population density. In addition, the data update process can be conducted quickly and is a comprehensive tool so that the level of accuracy can be recorded properly. In addition, the use of GIS can help to make the sustainability changes that occur in some places, more understandable [10].

In terms of research, sustainability is a topic that continues to increase and is discussed in various fields. In addition, there is also a lot of literature on sustainability topic implemented into research. Sustainability has 3 main dimensions: economic, social and environmental [11]. The results of this research are addressed to relevant decision makers, to help develop some strategies to improve the sustainability of the palm oil industry.

2. Research Methods

The stages of the research can be seen in Figure 1. The process begins by determining the main dimensions and indicators in the palm oil industry. These parameters and indicators were obtained based on the literature review of previous research with topic of the palm oil industry. These parameters and indicators were then reidentified and used as part of this research.

After the dimensions and indicators are determined, the data collection process is carried out based on the operational conditions of PT. ABC (one of Indonesian palm oil company) and questionnaires given to respondents with a knowledge or work in palm oil industry. Then, the performance of each location is carried out based on the data obtained. The focus area of this research is plantation/palm oil which is part of the palm oil industry.

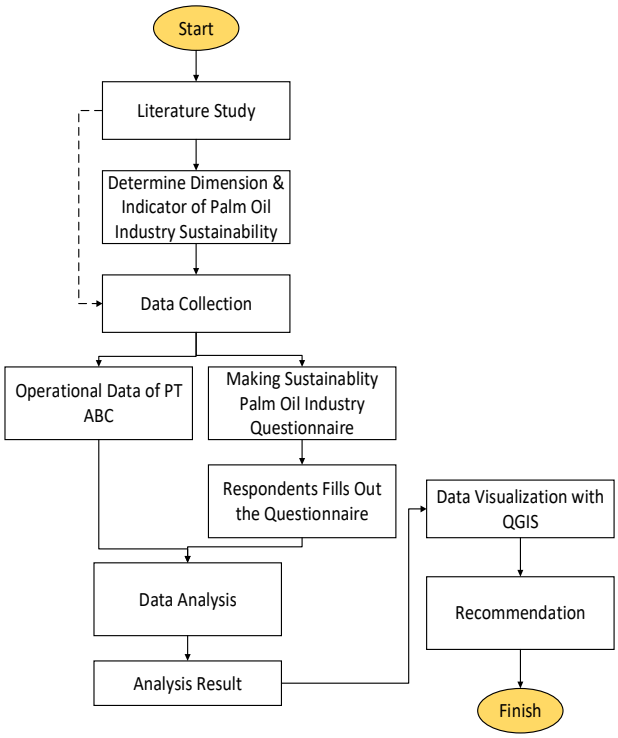

Figure 1. Overall Framework

2.1. Dimension & Indicator Determination

Based on several literatures and papers that discussed the sustainability indicators of the palm oil industry, the dimensions and indicators that will be used in this paper are as follows in Table 1.

Table 1.Sustainability Dimensions & Indicators

Dimension	Code	Indicator
Economy	E1	Cargo Loss
	E2	Cargo Quality
	E3	Field Productivity
	E4	Average salary (in IDR)
	E5	Company's document validity
	E6	Worker's document validity
	E7	Company's procedure
Social	S1	Fatality rate while working
	S2	Fatality rate while not working
	S3	Incident rate
	S4	Worker's personal rights
	S5	Worker & local community's life
	S6	Work Safety
	S7	CSR
Environment	L1	Waste management
	L2	Water consumption
	L3	Water contamination found
	L4	Water contamination above
	L5	Soil Condition
	L6	Frequency of fires
	L7	Use of fire usage for land

2.2. Data Collection

The process of collecting data in this study will be divided to the primary and secondary data. Primary data is obtained by using the questionnaire and using the operational data of PT. ABC. The process of obtaining primary data begins with field observation at PT. ABC receive relevant data from the company. The questionnaire contains the question of operational data of oil palm companies and operational information that is required for the research. Qualitative data will be collected using a questionnaire method and given to experts/related parties who have a knowledge of the sustainability indicators used in this paper, or those who have a good background in the palm oil industry. The secondary data will be obtained from the results of the previous research with relevant topics.

2.3. Data Analysis

Indicator data that obtained will be calculated using the multi criteria analysis (MCA) method. This method is used in complex decision making to achieve predetermined goals. The criteria and sub-criteria that used in this paper will be weighted according to the importance of these attributes and will be compared with other criteria [12].

In order to calculate the weight of the criteria in the study, a questionnaire survey method will be conducted with related experts. The results of the questionnaire survey will then be used to determine the weight of each criterion. These criteria will be divided into groups and assessed using a certain rating scale. These values are known based on the priority values of the criteria between one another and their relationship to the goals to be achieved [12]. Each criterion will then be examined using a pairwise comparison matrix which is described in Table 2 [12].

Table 2. Pairwise comparison matrix

	Criteria	Criteria	Criteria	Criteria
Criteria	1	a12	a13	a14
Criteria	a21	1	a23	a24
Criteria	a31	a32	1	a34
Criteria	a41	a42	a43	1

The value of a12 is the comparison value of the value of criterion 1 (row) with the value of criterion 2 (column). This comparison is conducted to find out the importance value between criterion 1 and criterion 2 [13], [14]. After the pairwise comparison matrix is completed, the priority value of each criterion will be compared between one correspondent and another respondent using the geometric multiplicity method using the following equation:

$$Geometric\ Multiplicity = \sqrt[n]{X_{1,1} \times X_{2,1} \times \ldots . \times X_{i,j}}$$

With:

- $X_{i,j}$ = Value of row i, column j in matrix
- n = the quantity number of data

Then, the data processing process will be carried out using the normalization method and the each indicator are to be weighted to finally get the order of importance for each alternative that used in this research [13]. Normalization process will be conducted by finding the lowest and highest values of a data, and then calculations are carried out using the actual value of the data, with the following equation:

$$Normalization = \frac{Actual\ Value - Min\ Value}{Max\ Value - Min\ Value}$$

2.4. Visualization

Visualization stage with GIS (Geographic Information System) using the QGIS application will be conducted after the analysis process completed. Each location of the oil palm industrial area where the research placed will be depicted on a map. There is a scale used in the visualization process, ranging from red to green, as described in Table 3.

If the value of a location category is low or unsustainable, a scale color that tends to be red will appear. However, if the performance of oil palm is good or sustainable, it tends to be depicted in green. In the final stage, based on the results of the GIS, the actual conditions of sustainability of each place will be obtained as well as recommendations for practitioners.

Table 2. Sustainability Scale

N	Scale		Category	Color &
1	0 - <10		Very	#ff0101
2	10 - <30		Unsustainable	#ff7c01
3	30 - <50		Less	#ffc001
4	50 - <70		Quite	#ffff00
5	70 - <90		Moderate Sustainable	#ffff66
6	90 s/d 100	90 to	Sustainable	#ccff99
		92 to		#99ff99
		94 to		#00ff01
		96 to		#33cc33
		98 to 100		#009901

3. Results and Discussions

The process begins by obtaining data from each respondent and calculating the weights by performing a pairwise comparison matrix, geometric multiplicity for each respondent and then

normalizing each of these indicators. The example results of pairwise comparison matrix and geometric multiplicity from one of the location and dimension of these calculations are written in the following Table 4 and Table 5.

The next step is to divide each value in the table by the total in each column. The result data in matrix will be calculated as shown in Table 6.

Finally, priority of each indicator is then divided by the total that contained in Table 6, (example in Table 6 for E7 = 1.07) and divided by the total of the indicator itself (in this study, for E7 = 1.07/7 = 0.153). The result of this calculation is the priority of each indicator, as shown in Table 7.

In this paper, the level of importance of each dimension: Economic, Social and Environmental, will be referenced from previous research conducted by [15], with the level of importance of each dimension of Sustainability of Palm Oil Industry Performance of Economic = 0.2770, Social = 0.3184 and Environment = 0.4046.

Table 3.Pairwise comparison matrix

	E1	E2	E3	E4	E5	E6	E7
E1	1.00	0.50	0.44	0.67	0.44	0.40	0.40
E2	2.00	1.00	0.89	1.33	0.89	0.80	0.80
E3	2.25	1.13	1.00	1.50	1.00	0.90	0.90
E4	1.50	0.75	0.67	1.00	0.67	0.60	0.60
E5	2.25	1.13	1.00	1.50	1.00	0.90	0.90
E6	2.50	1.25	1.11	1.67	1.11	1.00	1.00
E7	2.50	1.25	1.11	1.67	1.11	1.00	1.00

Table 4. Average of geometric multiplication

Economy	E1	E2	E3	E4	E5	E6	E7
E1	1.00	0.88	0.88	0.96	0.85	0.84	0.83
E2	1.14	1.00	1.00	1.10	0.97	0.96	0.95
E3	1.14	1.00	1.00	1.10	0.97	0.96	0.95
E4	1.04	0.91	0.91	1.00	0.89	0.87	0.86
E5	1.17	1.03	1.03	1.13	1.00	0.99	0.98
E6	1.19	1.04	1.04	1.14	1.01	1.00	0.99
E7	1.20	1.05	1.06	1.16	1.03	1.01	1.00
Sum	**7.88**	**6.91**	**6.92**	**7.59**	**6.72**	**6.63**	**6.56**

Table 5. Matrix of indicator

Eco.	E1	E2	E3	E4	E5	E6	E7	**Sum**
E1	0.13	0.13	0.13	0.13	0.13	0.13	0.13	**0.89**
E2	0.14	0.14	0.14	0.14	0.14	0.14	0.14	**1.01**
E3	0.14	0.14	0.14	0.14	0.14	0.14	0.14	**1.01**
E4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	**0.92**
E5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	**1.04**
E6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	**1.06**
E7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	**1.07**
Sum	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**7.00**

Table 6. Weight for each indicator

Criteria	Weight	Criteria	Weight	Criteria	Weight
E1	0.127	S1	0.152	L1	0.145
E2	0.145	S2	0.142	L2	0.145
E3	0.144	S3	0.148	L3	0.143
E4	0.132	S4	0.139	L4	0.145
E5	0.149	S5	0.133	L5	0.137
E6	0.151	S6	0.150	L6	0.139
E7	0.153	S7	0.136	L7	0.145
Total	1.000	Total	1.000	Total	1.000

After getting the weight of each indicator for indicators E1 and E2, the calculation is continued by using operational data of PT ABC in period of January to April 2022. E1 focuses on the difference of the amount of goods/cargo received by the client/consignee. compared to the amount of goods/cargo sent from the plantation/location of origin. E2 focuses on the decrease/increase in the quality of the goods/cargo received by the client/goods recipient. compared to the value of the quality sent from the plantation/location of origin.
The calculation process for these two indicators is carried out separately compared to other indicators that using a questionnaire. First is to find the maximum and minimum values for each location data, and then the normalization process is carried out from the data as shown in Table 8.

As for other indicators, the performance value is based on the selection of answers of respondent to the questionnaire where each answer choice in each question has its own value with a scale of 20 to 100. The result of respondent response to sustainability performance at East Kalimantan is showed at Table 9.

Each value of these indicators from each respondent is being averaged to get the actual value of each indicator. Then normalization and multiplication by weights of each indicator are carried out with calculations that have been previously written in Tables 4 to Table 7. Finally, the value of each indicator at the location can be obtained as written in the following Table 10, Table 11, Table 12 and Table 13 below.

Table 7. E1 & E2 indicators calculation

Jak Luay. Kalimantan Timur	**LOSS**		**QUALITY**	
			MOIST	**DIRT**
	Kg	**%**	**Value**	**Value**
Min	-300	-3.097%	-2.680	-5.090
Max	150	1.079%	3.340	1.230
Actual	-39.12	-0.292%	-0.455	-1.732
Normalization		**67,166**	**36,955**	**53,137**

Table 8. Questionnaire Result

Respondent	1	2
Location	Jak Luay. East Kalimantan	Jak Luay. East Kalimantan
E3	100	60
E4	100	100
E5	100	100
E6	100	80
E7	100	100
S1	100	100
S2	80	100
S3	80	80
S4	60	100
S5	100	100
S6	100	100
S7	100	80
L1	100	60
L2	100	100
L3	80	100
L4	100	100
L5	100	100
L6	100	100
L7	100	100

Table 9. Economy sustainability score

Code	Min.	Max	Actual	Norm.	Weight	Score
E1	-3.097%	-1.079%	-0.292%	67.166	0.127	8.527
E2	-2.680 -5.090	3.340 1.230	-0.455 -1.732	36.955 53.137	0.145 0.145	6.518
E3	60	100	80	80	0.144	11.558
E4	100	100	100	100	0.132	13.181
E5	100	100	100	100	0.149	14.879
E6	80	100	90	90	0.151	13.569
E7	100	100	100	100	0.153	15.252
Total Nilai Kinerja Ekonomi						**83.483**

Table 10. Social sustainability score

Code	Min.	Max	Actual	Norm.	Weight	Score
S1	100	100	100	100.00	0.152	15.192
S2	80	100	90	90.00	0.142	12.736
S3	80	80	80	80.00	0.148	11.819
S4	60	100	80	80.00	0.139	11.156
S5	100	100	100	100.00	0.133	13.337
S6	100	100	100	100.00	0.150	14.993
S7	80	100	90	90.00	0.136	12.248
Total Social Sustainability Score						**91.480**

Table 11. Environment sustainability score

Code	Min.	Max	Actual	Norm.	Weight	Score
L1	60	100	80	80.00	0.145	11.618
L2	100	100	100	100.00	0.145	14.522
L3	80	100	90	90.00	0.143	12.879
L4	100	100	100	100.00	0.145	14.522
L5	100	100	100	100.00	0.137	13.686
L6	100	100	100	100.00	0.139	13.916
L7	100	100	100	100.00	0.145	14.522
Total Environment Sustainability Score						**95.665**

Table 12. Final score

Location	Dimension Value	Weight	Overall Score
Jakluay. Kaltim			
Economy	83.483	0.405	
Social	91.480	0.277	**89.577**
Environment	95.665	0.318	

This calculation process is carried out for each location in the research. After the overall calculation conducted and all value of sustainability performance from all locations has been obtained, then each score can be categorized with a predetermined scale written in Table 3. The results of the overall sustainability performance and its categories of one of the locations that calculated in this study are written in Table 14.

After all the sustainability value is obtained and each of the value is transformed into a category, it is finally can be visualized by using the QGIS application. The results of the visualization are as follows in Figure 2, Figure 3, Figure 4 and Figure 5.

Table 13. Categorized score

Lokasi	Score	Category
Jakluay. Kaltim		
Overall	87.813	Moderate Sustainable
Economy	83.483	Moderate Sustainable
Social	91.480	Sustainable
Environment	95.665	Sustainable

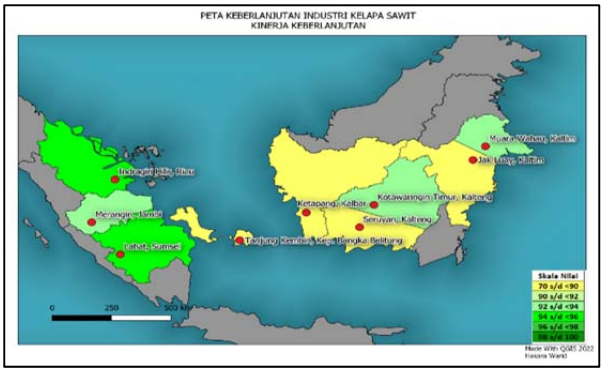

Figure 1. Overall performance visualization

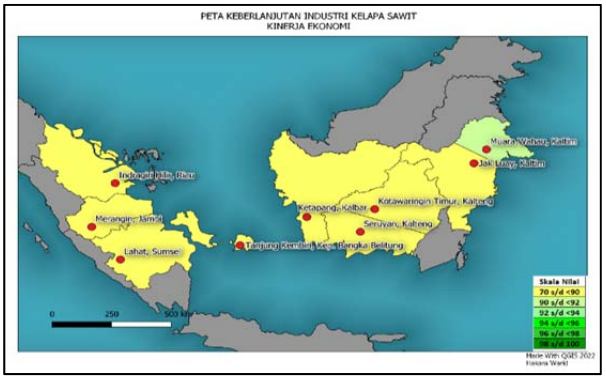

Figure 2. Economy performance visualization

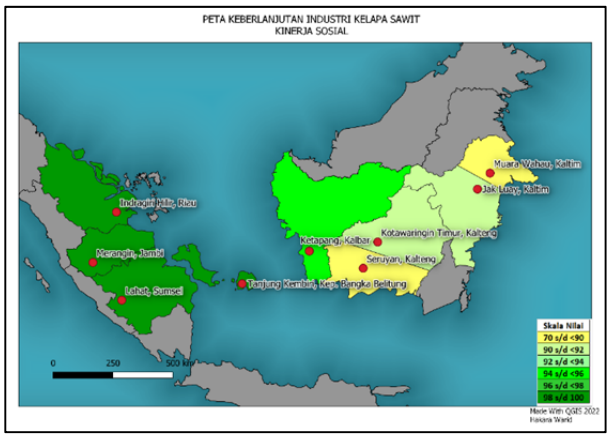

Figure 3. Social performance visualization

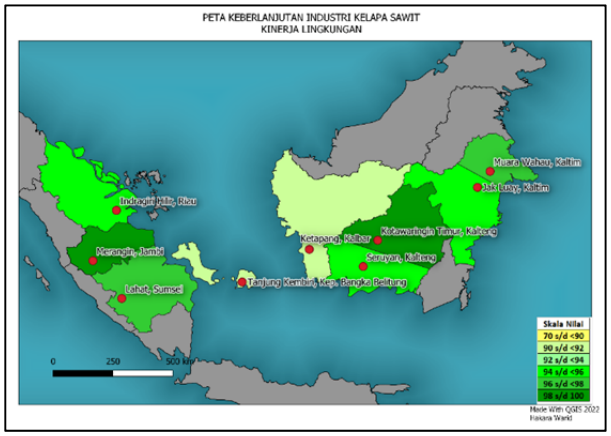

Figure 4. Environment performance visualization

4. Conclusion

In this paper an analysis of the sustainability performance of the palm oil industry was carried out in a several operational locations of palm oil companies that are located in Indonesia. The results of this study can provide insight to related parties or decision maker so that palm oil companies can make good strategies in terms of the sustainability of the palm oil industry in Indonesia. It should be noted that the weights of each indicator in each research will have such differences due to differences in opinions from experts and the indicators or parameter used in the research.

For future research, it can be continued by using other relevant indicators and apply in a real time GIS dashboard.

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