Study of Palm Oil Mill Effluent for Land Application Suitability in Lamandau Regency, Kalimantan Tengah Province

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ABSTRACT
This research puts the POME Land Application upfront and aims to evaluate the land suitability for POME land application and determine the suitable area for the land application in Lamandau Regency. This research uses Geographic Information System (GIS) to determine the land suitability for land application. The data required for this research are Slope, Hydrology, Geology, Soil, Settlement, Groundwater basin, and Palm Tree plantation. The analysis would be done spatially using scoring. All the data were transformed into raster data and every pixel of data contains a certain score and weight. From the results of data processing, it is known that the POME Land Application is most suitable in the southern part of Lamandau Regency with areas with low slopes and many oil palm plantations. In addition, the southern part also has ideal permeability for POME Land Applications. Administratively, the southern sub-districts such as Bulik Timur, Lamandau, Bulik, Menthobi Raya, and Semantu Jaya have more suitable land applications for POME. The five sub-districts contribute to more than 50% of the area more suitable for POME Land Applications from a total area of 118,849 ha.

Keywords: *POME; Land Application; Land Suitability; SMCE; GIS.*

1. INTRODUCTION

Palm oil has been famously known since it becomes one of the main exports of Indonesia's commodities. The emergence of Indonesia's Palm Oil started in the late '90s and reached its peak as it was the largest export commodity in 2015 [1, 2]. The statistic shows a significant increase in national palm oil production, rising from 8 million tonnes in 2010 to 17 million tonnes in 2016 [1]. this increasing trend encourages most several regions in Indonesia, particularly in Sumatera and Kalimantan Island opens small to large-scale Oil Tree Plantations, including Lamandau Regency, Kalimantan Tengah. Supported by its geophysical, climate, and hydrological characteristics, Lamandau Regency contributes to the Kalimantan Tengah Province's Palm Oil Fruit production with a percentage of 6% in 2020 [3]. It puts Lamandau Regency as the 5th largest Palm Oil producer with 308,358 ton in Kalimantan Tengah below Kotawaringin Timur, Seruyan, and Kotawaringin Barat, and Kapuas, respectively. To produce that amount, Lamandau Regency has 34,284 ha Palm Tree plantation and scattered in most of its sub-district with the largest plantation area is located at Bulik Sub-District, followed next by Semantu Jaya Sub-District, and Menthobi Raya sub-District [4].

The Palm Fruit is extracted to be Crude Palm Oil (CPO) or Other Palm Oil (OPO) in the mill. This process also yields waste in solid or liquid waste [5]. The latter is commonly known as Palm Oil Mill Effluent or POME and considered as wastewater. This process yields a

considerable amount of POME where 1 tonne of Palm Fruit on average generates 2.5 m3 of wastewater [6]. POME could pollute the environment [7] due to its characteristics with a high concentration of Nitrate, BOD, and COD hence it must be treated carefully in the dedicated Wastewater Treatment Plant. As part of the wastewater management, POME can be released to the river with strict regulation, or it can be reprocessed to be biogas [8] or reused to be fertilizer in the Palm Tree Plantation using the Land Application technique [9]. These methods are an effort to ensure the sustainability practice in the Palm Oil industry [10]

Land Application benefits the Palm Tree by adding P nutrients which are essential for its growth [9]. For the Palm Tree planter, it would reduce fertilizer cost significantly while at the same time decrease the volume of wastewater in the Wastewater Treatment Plant. Nevertheless, a land application could potentially harm the environment and causing pollution to groundwater, soil [11], and tributaries especially if the land application site is not suitable; causing POME to disperse uncontrollably. The impact could be more severe depending on the physical characteristic. For example, wetland and dryland will yield different impacts toward POME releasing [12]. Therefore, it is very important to determine the suitability of the land capability in retrieving POME for the land application. To avoid the pollution, Indonesian Government had issued several regulations regarding the POME land application namely Environmental Ministry Regulation Number 28 the Year 2003 and Environmental Ministry Regulation Number 29 Year 2003. Those regulations governed the technical terms and conditions for the POME land application practices.

This research puts the POME Land Application upfront and aims to evaluate the land suitability for POME land application and determine the suitable area for the land application in Lamandau Regency. We deal with the research question of what the criteria are determining the location of the POME Land Application and where are the suitable locations in Lamandau Regency.

2. METHOD

This research uses Geographic Information System (GIS) to determine the land suitability for land application. GIS is proven to be a very handful method in determining land suitability because it incorporates multi-data with bird-view perspective hence it could help answer all the research questions. For land suitability use, several approaches in the GIS method have been applied namely ELECTRE [13], multi-criterion [14-16], and Analytical Hierarchy Process (AHP) [17, 18]. For this research, we use the overlay method with scoring to determine suitability. the weighting factor for each criterion is calculated by the AHP process.

2.1. Research Location

This research takes place at Lamandau Regency. It sits in the northern part of Kotawaringin Barat Regency on the west border of Kalimantan Tengah and Kalimantan Barat. This regency comprises by 8 sub-districts of Batangkawa, Sematu Jaya, Bulik, Bulit Timur, Belantikan Raya, Delang, Menthobi Raya, and Lamandau. The location of Lamandau Regency can be seen in Figure 1 below.

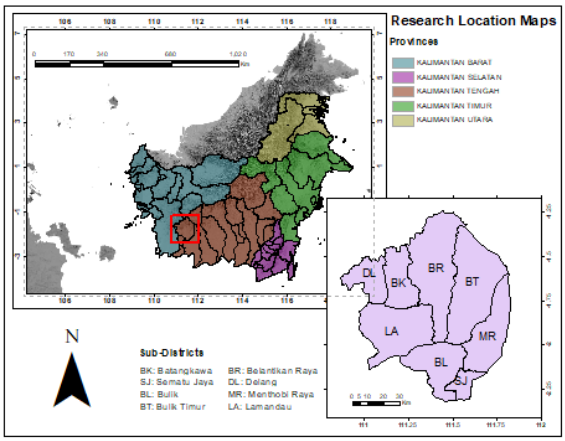

Figure. 1. Study Area

2.2. Data Collection

The data required for this research are Slope, Hydrology, Geology, Soil, Settlement, river flows, and Palm Tree plantation which are mostly from geological factors [19] and the regulation from the Indonesian Government (PermenLHK 28/2003, PermenLHK 29/2003). The slope is important in determining the contour and landform also useful in predicting the flow of POME when it is applied to land. Less slope would result from less flow of POME. The geological formation and soil help to find out the porosity and permeability and POME flow under the ground. Hydrological properties show the surface water mainly the main rivers and their tributaries. Settlement and the Palm Tree Plantation are anthropogenic factors and show human activities.

To determine the weighing factor, we employed Analytical Hierarchical Process. This is a very common method to determine a weight factor. AHP compares the importance of criteria to another criterion (e.g., which is more important to the suitability of POME land application? Slope or geological factor?) and the criterion of importance is translated into 10 degrees from equally important (0) to extremely very important (9). Each data was divided into 3 different categories with scores into 3 ranging from 3 (more suitable), 2 (moderately suitable), and 1 (less suitable). The score and weighing factor for criteria on each data can be seen in Table 1.

Table 1. Scoring Table of Criterion

Parameter	Criteria	Score
Slope	0-8	3
	8-15	2
	>15	1
Hydrology	>500 m	3
	100-500 m	2
	<100 m	1
Geology	Alluvium	3
	Sediment Rock	2
	Igneous Rock	1
Permeability	Clay	3
	Loam	2
	Sand	1
Distance to Settlement	>500 m	3
	100-500 m	2
	<100 m	1
	Basin	1
Palm Tree Plantation	Yes	3
	No	1

2.3. Data Analysis

The analysis would be done spatially using scoring. All of the data were transformed into raster data and every pixel of data contains a certain score and weight. By employing the GIS technique, the spatial data overlay to create land suitability for POME land application. Calculation of LAS was done using Arc GIS software as can be seen in Equation 1. The suitability quality is divided into 3 classes and the range of each class is derived from maximum and minimum values.

$$LAS = \sum w_i s_i \quad (1)$$

With LAS represents the POME Land Application Suitability, w_i is the weighing factor of variable i, and s_i is the score of variable i.

3. RESULTS AND DISCUSSIONS

3.1. Weighing Factor

We put six variables into the AHP process to determine the impact of each variable on POME Land Application sustainability. The initial score can be seen in Table 2.

Table 2. Weight Factor of Each Variable

	S	H	G	P	DS	PP
S	1.00	7.00	7.00	6.00	1.00	0.33
H	0.14	1.00	5.00	0.20	0.33	0.20
G	0.14	0.20	1.00	0.14	0.14	0.13
P	0.17	5.00	7.00	1.00	3.00	1.00
DS	1.00	3.00	7.00	0.33	1.00	1.00
PP	3.00	5.00	8.00	1.00	1.00	1.00

S: Slope, H: Hydrology, G: Geology, P: Permeability, DS: Settlement, PP: Plantation

Executing the AHP process, the weighing factors for each variable are 0.27 for slope, 0.06 for hydrology, 0.03 for geology, 0.20 for permeability, 0.17 for distance to settlement, and 0.28 for the palm tree plantation. This calculation yields a Consistency Index (CI) of -0.016 and a Consistency Ratio (CR) of -0.013. Because the CR is less than 0.1 then the weighing factor is reliable to use for further calculation.

3.2. Biophysical Characteristics of Lamandau Regency

Lamandau Regency sits on the southern border of Schwanner Mountain, a mountain range in the center part of Kalimantan Island. This mountain range influences most of the biophysical aspects in Lamandau Regency by supplying soils, regulating water, and carving morphology. Schwanner Mountain is located at the north part of Lamandau Regency hence Lamandau Regency is divided into two physiographic characteristics: mountainous in the north and great alluvial plain in the south. Schwanner Mountain consists of plutonoid rock such as tonalite and granite rock [20]. Acting as host-rock, those rocks produce baser soil, and the interaction with water washed away the mineral, yielding latosol soil including dystropept and tropudults. Weathering of rock also creates sediments that are accumulated in the southern part.

Lamandau's physiographic characteristics also affect the rainfall where the northern part has more rainfall than the south. Rainfall in the northern part area is accumulated in the river and flows to the south through the rivers and tributaries. Several great rivers are formed as the result of the rainfall accumulation namely Matu River, Palikodan River, and Bulik River. All of those rivers eventually the main river of Lamandau River. Lamandau River is the main river in Lamandau Regency, flowing through nanga Bulik, the capital area of Lamandau Regency to the Java Sea.

All of those physical characteristics yield various land cover and vegetation types ranging from lowland dense rainforest in the north area to swampy area in the south. People in Lamandau Regency also adjust themselves to the physical condition and build most of the settlements in the relatively flatter topography in the south causing the southern part becomes denser and have a much more built environment including palm tree plantation. The southern part of Lamandau Regency is the home for most palm tree plantations in Lamandau Regency. Low-flat morphology supports plantation to success along with the abundance of water from rainfall and river. The accumulation of soil in the southern part also helps palm trees in the plantation to develop and serves the nutrients they need.

All of those elaborations are classified into three categories according to Table 1. The result of the categorization can be seen in Figure 2.

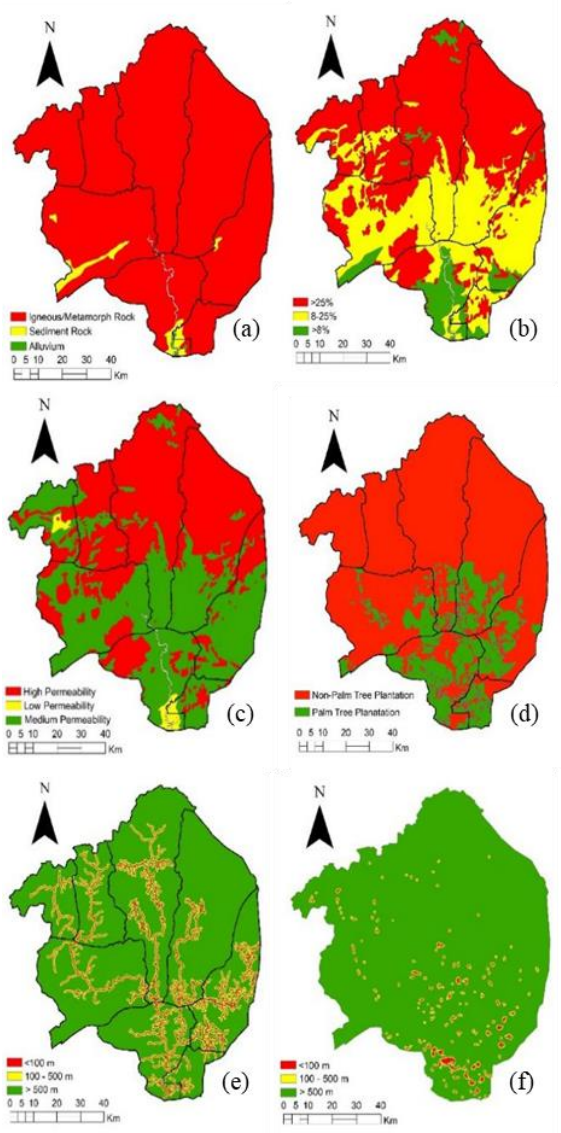

Figure. 2. Spatial Distribution of Each Criterion Used. (a) geological, (b), slope, (c), permeability, (d) existing plantation, (e) river streams, (f) settlement

There are 6 maps to demonstrate each physical characteristics that determine the land suitability of POME land application. Figure 2.a. shows how most of the Lamandau Regency lithology is igneous rock. With its poor permeability, igneous rock is considered not too well-fit for land application. Nevertheless, the slope and soil may enable the land application as shown in Figure 2.b. and Figure 2.c. The soil in the Southern part of Lamandau is dominated by thick-alluvial sediments with moderate permeability. They are not too loose to cause POME to directly infiltrate groundwater nor too tight to block the POME enter the ground. Slope characteristics are also flat to support the vertical movement of POME into the ground. Also, the map in Figure 2.d shows the existing Palm Oil Plantation. Another physical characteristic of hydrological can be seen in Figure 2.e where the river streams are accumulated in the southern part of Lamandau Regency. The southern part also hosts the most settlement. Figure 2.f visualizes the scattering pattern of settlement.

3.3. POME Land Application Suitability

The weighing factor and score from each variable are then multiplied and compounded to generate the land suitability. POME Land Application Suitability can be seen on the map in Figure 3.

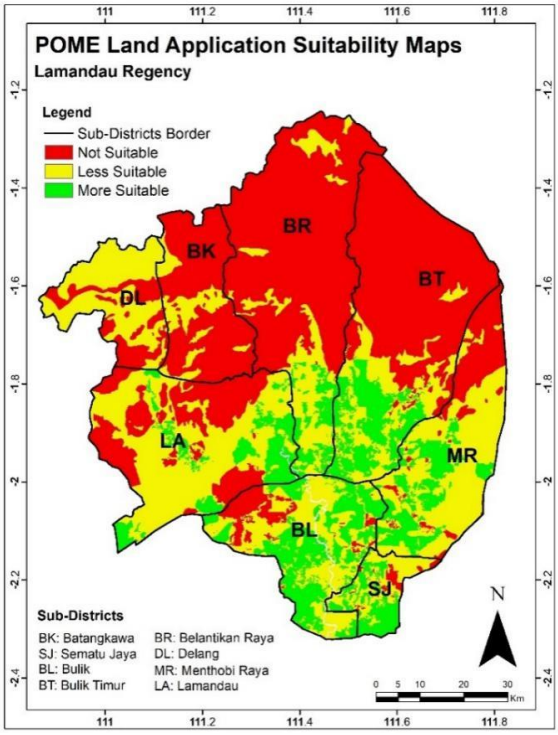

Figure. 3. Maps of Land Application Suitability in Lamandau Regency

Figure 3 illustrates how the POME Land Application is most suitable in the southern part of Lamandau Regency where it's less sloppy with more existing palm tree plantations. The southern part of Lamandau Regency also consists of moderate permeability soils which are ideal for POME Land Application. Nevertheless, the settlement disrupts the bulk area of palm tree plantation for the POME Land Application suitability where many settlements sit adjacent to or inside the palm tree plantation. This settlement is usually inhabited by farmers or a mess of the employee from large-scale plantation corporations.

Administratively, the southern sub-district like Bulik Timur, Lamandau, Bulik, Menthobi Raya, and Semantu Jaya holds the most more suitable POME Land Application. Those 5 sub-districts contribute to more

than 50% more suitable areas for POME Land Application from the total of 118,849 ha area. Meanwhile, northern part sub-districts of Belantikan Raya, Batangkawa, and Delang sub-districts are mostly not suitable for POME Land Application. The hilly topography with dense rain forest is far from a supporting factor for palm tree plantation let alone POME Land Application as shown by the study [21-23]. These areas are very critical to be preserved for sustainability and the ecosystem service they produce.

Table 3. Area of Class in Each Sub-District

Class	Sub-District	Area (ha)	Total (ha)
Not Suitable	Batangkawa	51,920	383,823
	Belantikan Raya	130,360	
	Bulik	10,204	
	Bulik Timur	110,975	
	Delang	15,322	
	Lamandau	42,546	
	Menthobi Raya	20,540	
	Sematu Jaya	1,956	
Less Suitable	Batangkawa	12,377	274,726
	Belantikan Raya	26,212	
	Bulik	37,123	
	Bulik Timur	28,969	
	Delang	36,379	
	Lamandau	68,526	
	Menthobi Raya	54,350	
	Sematu Jaya	10,791	
More Suitable	Batangkawa	7	118,849
	Belantikan Raya	9,688	
	Bulik	34,917	
	Bulik Timur	24,827	
	Lamandau	18,802	
	Menthobi Raya	20,420	
	Sematu Jaya	10,187	

POME Land Application in Lamandau District can be one of the efforts made to improve ecosystem services. Ecosystem services that can be enhanced with POME Land Applications in Lamandau District include soil support ecosystem services and maintenance of fertility as well as ecosystem services that support the nutrient cycle process. Judging from the ecosystem services, Lamandau Regency is relatively low, especially in the southern part of Lamandau Regency. Land Application POME which is applied in Lamandau District can improve soil support ecosystem services and maintenance of fertility as well as ecosystem services that support the nutrient cycle process.

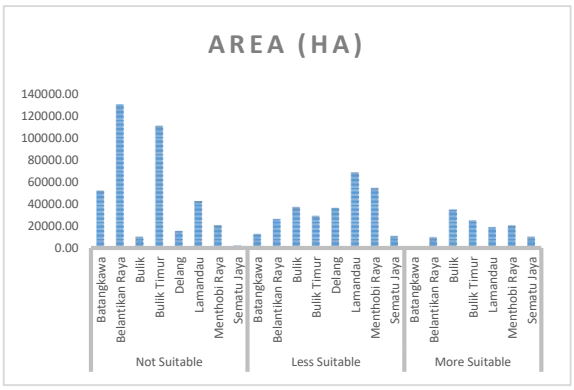

Figure. 4. Bar Graph of LAS in Each Sub-District

POME Land Application requires a certain permit to be done. This permit requires a thorough study through several considerations including the bio-physic-socio aspect at the desired area. The permit is strongly related to governmentality which is entered in the administrative unit such as sub-district. From the POME Land Application maps and the spatial distribution in the sub-district unit, it would be simpler to issue the permit by checking the suitability in the certain sub-district. This will strengthen the accountability and simplicity of the permit process for the local government especially if the map is used for the filtering step in the permitting process.

Figure 3 illustrates how the POME Land Application is most suitable in the southern part of Lamandau Regency where it's less sloppy with more existing palm tree plantations. The southern part of Lamandau Regency also consists of moderate permeability soils which are ideal for POME Land Application. Nevertheless, the settlement disrupts the bulk area of palm tree plantation for the POME Land Application suitability where many settlements sit adjacent to or inside the palm tree plantation. This settlement is usually inhabited by farmers or a mess of the employee from large-scale plantation corporations.

4. CONCLUSION

In implementing the AHP process on six variables, the weighing factor for each variable is 0.27 for slopes, 0.06 for hydrology, 0.03 for geology, 0.20 for permeability, 0.17 for distance to settlement, and 0, 28 for oil palm plantations. Judging from its biophysical characteristics, Lamandau Regency is influenced by the biophysical aspects of Mount Schwanner, a mountain in the central part of Kalimantan Island. The physiographic characteristics of Lamandau also affect rainfall where the northern part has more rainfall than the southern part. Rainfall in the northern part accumulates in rivers and flows southward through rivers and creeks.

All of them physically produce the land cover and vegetation types ranging from dense lowland rainforest in the north to swamps in the south. Lowland morphology supports the success of plantations along with the abundance of water from rainfall and rivers. In addition, the soil in the southern part of Lamandau is dominated by thick alluvial sediments with moderate permeability. They are not too loose, causing the POME to infiltrate the groundwater and also not too tight to prevent the POME from entering the ground.

From the results of data processing, it is known that the POME Land Application is most suitable in the southern part of Lamandau Regency with areas with low slopes and many oil palm plantations. In addition, the southern part also has ideal permeability for POME Land Applications. Administratively, the southern sub-districts such as Bulik Timur, Lamandau, Bulik, Menthobi Raya, and Semantu Jaya have the most suitable land applications for POME. The five sub-districts contribute to more than 50% of the area more suitable for POME Land Applications from a total area of 118,849 ha.

AUTHORS' CONTRIBUTIONS

Conceptualization: Hilary Reinhart, Suaduan Syahri; Methodology: Hilary Reinhart; Analysis: Hilary Reinhart, Dalili Ghaisani Hashifah; Cartography and Spatial Data: Hilary Reinhart, Linggar Esty Hardini; Writing: Hilary Reinhart, Dalili Ghaisani Hashifah; Review: Hilary Reinhart

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