2016. Model Assessment of Land Suitability Decision Making for Oil Palm Plantation

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Model Assessment of Land Suitability Decision Making for Oil Palm Plantation

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***Abstract*—Model assessment of Land suitability (MAOLS) is a valuable tool for palm land, and it is used to manage the natural resource in the land clearing of oil palm plantations. The model is applied to a decision support system (DSS) for oil palm plantation land clearing problem. This issue is intended to avoid excessive land clearing, therefore the efficient analysis in decision making is necessary. DSS model was used with Multi-Criteria Decision Making (MCDM) using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method for 14 parameters on land's class criteria and has four alternatives of oil palm plantations was applied. The first phase of testing uses direct weighting on TOPSIS, and it obtained the fourth land as the potential for oil palm plantations clearing with the scoring values are 0,578. The second stage of the Analytical Hierarchy Process (AHP) method is used to determine the effectiveness of the proposed model. This result showed the effectiveness of the similarity ranking on alternative output in recommending an alternative to the manager to give consent to the land clearing of oil palm plantations in East Kutai, Indonesia.**

Keywords*—*assessment; land suitability; oil palm plantations; TOPSIS.

I. INTRODUCTION

An assessment model of DSS has been widely applied to the analysis process in making a decision on the other issues such as environmental impact assessment [1], environmental impact assessment of agriculture [2] or assessment of tobacco fields [3]. This problem makes the assessment model for conformity assessment classification of oil palm land becomes appropriate and effective in selecting the location of oil palm so that the ecosystems contained over there can be properly maintained if not all of the land is used. The misuse of land clearing can cause forest changing to agriculture and other environmental damaging. It can interfere with a variety of its species inside, such as the problem of conversion of forest to agriculture [4], [5].

In the economic point of view, the oil palm plantation is one of the most important assets for regional development in Indonesia, especially in Sumatra and Kalimantan. According to data from the Central Statistics Agency (Badan Pusat Statistika) from Indonesia on paper [6] mentioned that the distribution company of the oil palm plantations clearing in Indonesia such as in Sumatra island has the highest ratings that reached 63%. Meanwhile, the permanent effects of excessive land clearing every year can damage the environment and social aspect, and it takes place in the area location of the locals [7]. it causes the decrease of forest land and changes the ecosystem, soil pH, etc. Other effects may also cause soil erosion which is caused by the unavailability of roots left over inside of the forest and the social aspect may cause the society lose their plantation [8].

Multi-Criteria Decision Making (MCDM) method with TOPSIS is used for assessing the suitability classification of oil palm plantation. The proposed MAOLS is used to support decision-making in the assessment of the type of oil palm plantations in East Kutai, East Kalimantan province of Indonesia. The objective of land suitability assessment helps the government or investors to choose the location of oil palm plantations based on the criteria of land types. The proposed model assessment of this study is shown in Fig. 1.

This model is used to provide an assessment of each criteria types of land for the stakeholders can determine the location of suitable land. The final result of this model is the ranking of land based on the TOPSIS direct-weighting method paired with and it uses weights that paired with the comparison parameters contained in the Analytical Hierarchy Process (AHP). The proposed model will perform decision analysis, the weighting criteria and class suitability assessment are based on the results of data belonged.

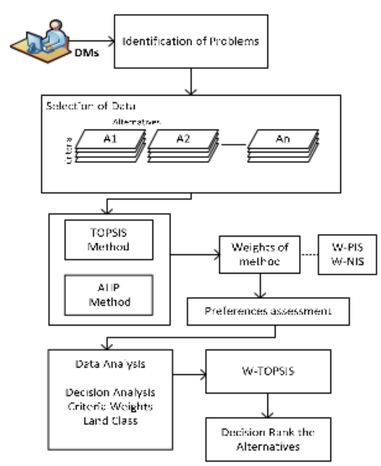

Fig. 1. Proposed model assessment of palm plantation

II. TOPSIS METHOD

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is a technique to obtaining the distance between the alternative values are positive and negative matrices, and it determines the preference value for each alternative decision. It was first developed by Hwang and Yoon in [9]. Generally, the procedure of TOPSIS consists of several steps, they are making normalized decision matrix, weight normalization, positive ideal solutions (PIS) and negative ideal solutions (NIS) [9]. TOPSIS method requires alternative (A1) on each criterion that is normalized (C1) [9]–[11].

TOPSIS is based on a concept that each better alternative has lowest distance from positive ideal solution (PIS) and the one having the highest distance is the negative ideal solution (NIS) [12]. PIS presents the best solution which maximizes the benefit attribute and minimizes the cost attribute whereas NIS presents the converse, i.e. negative solution minimizing benefits attribute and maximizing cost attribute while NIS provides the opposite such as the negative solution that minimizes negative attributes and maximizes cost attribute [13]. Normalization is done as equation (1) with calculated the normalized decision matrix R (=[r_{ij}]). The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \text{; where } i=1,2,\dots,m, \text{ and } j=1,2,\dots,n. \quad (1)$$

where r_{ij} and x_{ij} are normalized decision value matrix m is the number of alternative solutions and n is the number of objective values in criteria.

In equation (2), (3) and (4) each positive ideal solutions (PIS) w^+ and negative ideal solutions (NIS) w^- can be determined by the normalized rating (v_{ij}).

$$(v_{ij}) = w_i r_{ij}; \text{ where } i = 1,2,\dots,m, \text{ and } j = 1,2,\dots,n. \quad (2)$$

where w_i is the weight for the jth objective value and v_{ij} is the weighted normalized decision value matrix.

$$v^{+(PIS)} = (v_1^+, v_2^+, \dots, v_n^+) = \{(Max\, v_{ij} | j \in J), (Min\, v_{ij} | j \in J^-)\} \quad (3)$$

$$v^{-(NIS)} = (v_1^-, v_2^-, \dots, v_n^-) = \{(Min\, v_{ij} | j \in J), (Max\, v_{ij} | j \in J^-)\} \quad (4)$$

Subsequently, calculate v_1^+ if the max value of ${}_1v_{ij}$ to the benefits attribute and min ${}_1v_{ij}$ to the cost attribute. Calculate v_1^- if the min value of min${}_1v_{ij}$ to the benefits attribute and max${}_1v_{ij}$ to the cost attribute. Equation (5) is the alternative distance of S_i with positive ideal solutions (PIS) is given as:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_i^+ - v_{ij}^+)^2} \quad ; \quad i = 1,2,\dots,m. \quad (5)$$

Equation (6) is the distance between the negative ideal solutions (NIS) alternative (Ai) calculated as follows:

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_i^- - v_{ij}^-)^2} \quad ; \quad i = 1,2,\dots,m. \quad (6)$$

Get the TOPSIS rank by calculating the relative closeness to the ideal value solution. The preference value in equation (7) for each alternative (Ai) is calculated follow.

$$C_i = \frac{S_i^-}{S_i^- + S_i^+} \; ; \; i = 1,2,\dots,m. \quad (7)$$

III. RESULTS OF ANALYSIS

A. Model weighting of Decision Making

The MAOLS requires 14 parameters as the input is used for making decisions. They are Agro climatic zone (ACZ), Oldeman (Od), height of the sea surface (HSs), Area and slope forms (ASf), Stone on the surface and in the soil (SSS) , solum soil depth (SSD), ground water depth (GWD), soil texture (ST), soil structure (SSt), soil consistency (SC), Class drainage (CD), Erodibility (Ed), pH and Soil fertility (SF).

The output criteria of this model is classified into four types, namely S1 defined as the Land Suitability highly recommended, S2 defined as the Land Suitability moderately recommended, S3 defined as Land Suitability marginally recommended and N defined as not recommended (unsuitable). It is used to decide the choice of location which is very representative to use as palm oil plantations. The parameters and the type of criteria Land Suitability are used in this research summarized in Table I.

The first phase of testing use TOPSIS which directly filled by the decision makers (DMs), the weight does not include comparison matrixes, such as the weight input (W_1) = 0.02 ; 0.05 ; 0.02 ; 0.05 ; 0.1 ; 0.15 ; 0.04 ; 0.05 ; 0.1 ; 0.15 ; 0.04 ; 0.04 ; 0.04 ; 0.15. While, the second phase of testing used the weight pair comparisons in AHP method.

TABLE I. LAND SUITABILITY (LS) CLASSIFICATION CRITERIA FOR OIL PALM PLANTATIONS

Parameter (P)	**Capability element**	**S1** (LS highly)	**S2** (LS moderate)	**S3** (LS Marginally)	**N** (unsuitable)
ACZ	Agro Climatic Zone	A: 9/2	B2: 7-9/2-3	D1: 3-4/2	D2: 3-4/2-3
Od	Oldeman	B1: 7-9/2	C1: 5-6/2	C2: 5-6/2-3	D3: 4-6/6 E1: 3/2 E2: 3/2-3 E3: 3/4-6
Hss	Height of the sea surface	25 – 200 meter	200 – 300 meter	300 – 400 meter	< 25 meter or > 400 meter
ASf	Area / slope forms	Form flat wave < 10% (4,5°)	Surf wave 10 – 22 % (4,5° – 10°)	Hill wave 22 – 50 % (10° – 22,5°)	Hill mountain > 50 % (> 22°)

TABLE I. LAND SUITABILITY (LS) CLASSIFICATION CRITERIA FOR OIL PALM PLANTATIONS (CONT.)

Parameter (P)	**Capability element**	**S1** (LS highly)	**S2** (LS moderately)	**S3** (LS Marginally)	**N** (unsuitable)
SSS	Stone on the surface and in the soil	< 10%	10 – 25%	25 – 50%	> 50%
SSD	Solum soil depth	> 100 cm	50 – 100 cm	25 – 50 cm	< 25 cm
GWD	Ground water depth	> 100 cm	50 – 100 cm	25 – 50 cm	< 25 cm
ST	Soil texture	Sandy clay Loam clay Sandy clay	Argillaceous clay Sandy loam	Sandy clay Dusty sand Sandy loam	Coarse sand
SSt	Soil structure	Strong crumb Medium glob	Medium crumb Medium glob	Weak glob	Unstructured Massive
SC	Soil consistency	Very loose Not sticky	Loose Closely sticky	Hard Sticky	Very hard Very sticky
CD	Class Drainage	Well	Somewhat excessive Moderately well	Quickly Slowly	Very poor Poor excess drain Swamped
Ed	Erodibility	Very low	Medium	High	Very High
pH	pH	< 6,1	6,1 – 6,5	6,6 – 7,0	> 7,0
SF	Soil fertility	High	Medium	Low	Very low

After the result of weighted value on the parameter of suitability land was obtained, then the decision makers (DMs) inputs the criteria value between 1 to 9, where the range of criteria value is determined by the plantation expert.

TABLE II. THE RANGE OF CRITERIA VALUES AND THE STATUS OF SUITABILITY LAND

Land suitability classification	**The range of Criteria values**	**Status of Suitability land**
S1	7 - 9	Highly suitable
S2	5 - 7	Moderately suitable
S3	3 - 5	Marginally suitable
N	1 - 3	unsuitable

This value indicates the degree of land suitability and should have a high criteria value for the good recommendation. In this research, S1 (highly suitable) has a value of between 7 to 9, S2 (Moderately suitable) between 5 to 7, S3 (Marginally suitable) between 3 and 5, and N (unsuitable) between 1 to 3. The range of criteria values and the status of suitability land as shown in Table II.

B. Suitability rate using alternative weight

Data conversion results for the alternative suitability rate of each criterion for first stage of testing is using weights (*W1*) directly with TOPSIS (W-TOPSIS) such as the parameter values in Table III.

TABLE III. SUITABILITY ALTERNATIVE RATE OF EACH CRITERION

Land Alternativie	**Parameter (Criteria)**													
	ACZ (C1)	**Od** (C2)	**Hss** (C3)	**ASf** (C4)	**SSS** (C5)	**SSD** (C6)	**GWD** (C7)	**ST** (C8)	**SSt** (C9)	**SC** (C10)	**CD** (C11)	**Ed** (C12)	**pH** (C13)	**SF** (C14)
Land 1	8	6	7	5	9	5	3	4	2	6	9	7	5	8
Land 2	7	4	5	2	5	2	5	2	7	6	8	3	4	7
Land 3	6	5	8	8	6	5	9	3	5	3	4	9	6	6
Land 4	3	8	4	7	4	9	4	7	4	5	6	5	9	4

The first stage is applied to normalize the data of the decision matrix in Table III, and the results of the alternative suitability can be seen in matrix:

$$X = \begin{bmatrix} 8 & 6 & 7 & 5 & 9 & 5 & 3 & 4 & 2 & 6 & 9 & 7 & 5 & 8 \\ 7 & 4 & 5 & 2 & 5 & 2 & 5 & 2 & 7 & 6 & 8 & 3 & 4 & 7 \\ 6 & 5 & 8 & 8 & 6 & 5 & 8 & 3 & 5 & 3 & 4 & 9 & 6 & 6 \\ 3 & 8 & 4 & 7 & 4 & 9 & 4 & 7 & 4 & 5 & 6 & 5 & 9 & 4 \end{bmatrix}$$

Furthermore, formed the matrix normalization R_1 to R_4 that is applied with the same steps with the alternative x_{ij} on each alternative line by using equation (1).

The result of the normalization of attribute values process is followed by creating a normalized matrix *(R)* and multiplying weight (*W*) with the value of each attribute to gain the weight value. The results of the normalized matrix (*R*) and the result of multiplying weight (*W*), then the results of the matrix (v_{ij}) of the weighting is contained in the weight values as in equation (2). The results of the weighting matrix as follows:

$$R = \begin{bmatrix} 0{,}636 & 0{,}505 & 0{,}564 & 0{,}420 & 0{,}716 & 0{,}430 & 0{,}262 & 0{,}026 & 0{,}206 & 0{,}583 & 0{,}641 & 0{,}547 & 0{,}398 & 0{,}623 \\ 0{,}557 & 0{,}337 & 0{,}403 & 0{,}168 & 0{,}398 & 0{,}172 & 0{,}437 & 0{,}026 & 0{,}722 & 0{,}583 & 0{,}570 & 0{,}234 & 0{,}318 & 0{,}545 \\ 0{,}477 & 0{,}421 & 0{,}645 & 0{,}671 & 0{,}477 & 0{,}430 & 0{,}786 & 0{,}038 & 0{,}516 & 0{,}291 & 0{,}285 & 0{,}703 & 0{,}477 & 0{,}467 \\ 0{,}239 & 0{,}674 & 0{,}322 & 0{,}587 & 0{,}318 & 0{,}775 & 0{,}349 & 0{,}090 & 0{,}413 & 0{,}486 & 0{,}486 & 0{,}390 & 0{,}716 & 0{,}311 \end{bmatrix}$$

$$W = \begin{bmatrix} 0{,}013 & 0{,}025 & 0{,}011 & 0{,}021 & 0{,}072 & 0{,}065 & 0{,}010 & 0{,}001 & 0{,}021 & 0{,}087 & 0{,}026 & 0{,}022 & 0{,}016 & 0{,}093 \\ 0{,}011 & 0{,}017 & 0{,}008 & 0{,}008 & 0{,}040 & 0{,}026 & 0{,}017 & 0{,}001 & 0{,}072 & 0{,}087 & 0{,}023 & 0{,}009 & 0{,}013 & 0{,}082 \\ 0{,}010 & 0{,}021 & 0{,}013 & 0{,}034 & 0{,}048 & 0{,}065 & 0{,}031 & 0{,}002 & 0{,}052 & 0{,}044 & 0{,}011 & 0{,}028 & 0{,}019 & 0{,}070 \\ 0{,}005 & 0{,}034 & 0{,}006 & 0{,}029 & 0{,}032 & 0{,}116 & 0{,}014 & 0{,}004 & 0{,}041 & 0{,}073 & 0{,}017 & 0{,}016 & 0{,}029 & 0{,}047 \end{bmatrix}$$

The next step will be done to find the value of positive ideal solutions (PIS) w^+ and negative ideal solutions (NIS) w^- in making this decision. Then the weight rating normalized by Eqs. (3) and (4) can be determined. This stage is aimed to find the value of PIS w^+ and NIS w^- to making a decision with the weight value as illustrated in Fig. 2.

$$w^{+\,(PIS)} = \{0{,}013;\ 0{,}034; 0{,}013;\ 0{,}034;\ 0{,}072;\ 0{,}116;\ 0{,}031;\ 0{,}004;\ 0{,}072;\ 0{,}087;\ 0{,}026;\ 0{,}028;\ 0{,}029;\ 0{,}093\}$$

$$w^{-\,(NIS)} = \{0{,}005; 0{,}017; 0{,}006; 0{,}008;\ 0{,}032;\ 0{,}026;\ 0{,}010;\ 0{,}001; 0{,}021;\ 0{,}044;\ 0{,}011;\ 0{,}009;\ 0{,}013;\ 0{,}047\}$$

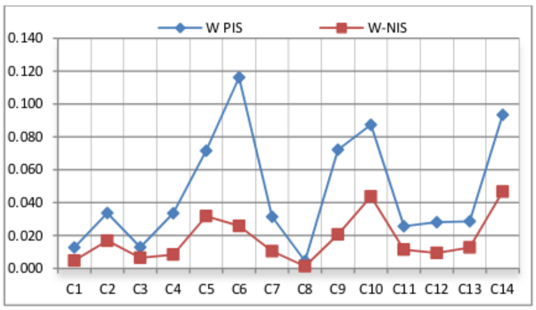

Fig. 2. The weighting distance PIS and NIS of value criteria

Based on the value weight distance of each alternative PIS using equation (5) and NIS equation (6) will be carried out to the next stage of the process to get preference in order to be an alternative value in the ranking. High scores will be an alternative that can be used by DMs in making a decision on the suitability assessment of oil palm plantations.

C. Alternative suitability rate to Decision Making

The first phase of testing produces the value rankings which are used as the recommendation for managers in decision-making. In this model, the first rank has no guarantee that the DMs is needed to be done , so it requires a comparison with other models such as the AHP to determine whether the alternatives such decision is effective or not. This model is used to produce each alternative (A_i) using equation (7). The alternative outputs of all four fields are as follows:

$$Land_1 = \frac{0{,}062}{0{,}079 + 0{,}062} = \frac{0{,}062}{0{,}140} = 0{,}439$$

$$Land_2 = \frac{0{,}078}{0{,}104 + 0{,}078} = \frac{0{,}078}{0{,}182} = 0{,}429$$

$$Land_3 = \frac{0{,}069}{0{,}081 + 0{,}069} = \frac{0{,}069}{0{,}150} = 0{,}460$$

$$Land_4 = \frac{0{,}103}{0{,}075 + 0{,}103} = \frac{0{,}103}{0{,}177} = 0{,}578$$

The process of ranking depicts that the land contained in the Land 4 with a score of 0,578 with TOPSIS value rankings. The following test will be done in the second stage by using AHP to determine the weights based on the comparison of the parameters according to the number of criteria matrix. This process only takes the value of the weighting process used AHP and then it is performed by using the ranking process of TOPSIS method as well as on the weight (*W2*) is W-AHP . Assuming the parameter data and the criteria data used is the same as the first stage of assessment. The results of land suitability ranking of the first phase of testing can be seen in Table IV.

TABLE IV. PROXIMITY OUTPUT OF EACH ALTERNATIVE

Approaches/ Land Alternatif	Interpretability with W-TOPSIS	Rank	Interpretability with W-AHP	Rank
Land 1	0,439	3	0,480	2
Land 2	0,429	4	0,432	4
Land 3	0,460	2	0,478	3
Land 4	0,578	1	0,564	1

The results of the second phase of the test are known to the output rankings that also recommend Land 4 with the result of the ranking is 0,564. This result showed that both of the rankings are using the weighting TOPSIS directly and it is better than using AHP method , but the second output of weighting in producing alternative decision did not change the output alternative to land 4. The output of the ranking based on the graph as viewed in Fig. 3.

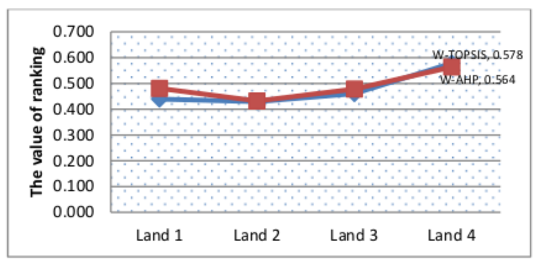

Fig. 3. Results on land with weighting W-TOPSIS and W-AHP

IV. CONCLUSION

The ranking result of land suitability based on TOPSIS and alternative output shows that the model produces land 4 to be recommendation. This alternative is the result of the process model analysis TOPSIS and AHP weights in generating recommendation land. The output of the ranking would recommend the location of the land on high preference value and as the reference to give license for establishment of oil palm plantations clearing. The testing model uses the data criteria from the experts' survey team of the government, and uses the weights according to the method proposed to produce a preference on the ranking score of all the land. Fig. 3 show that the Land 4 has the score of 0,578 W-TOPSIS and 0,564 on the W-AHP. This model becomes individually power manager to support a future decision for the clearing of oil palm plantations, so the clearing of oil palm plantations can be more effective. Evidence shows the complexity TOPSIS method of choice as in the previous study [14]. Our future study will focus on group of decision making for dimensional parameters of various aspects of parameters, such as land suitability parameter aspect, soil type, environmental and social impacts as well as economic and business aspects. Hybrid method is required methods for performing hybrid on MCDM as what has been done with other methods on the same issue [15]. The further valuation technique is required to make a collaboration which involves various stakeholders such as paper [16], [17] with Group Decision Making (GDM) model and the web-GIS models which is expected to yield better results. Therefore, it is expected to be more maximal results in decision support, and further research will be done to make the dimensional parameters of several aspects, such as the suitability of land, type of soil, environmental and social impacts as well as economic and business aspects.

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