

DECISION SUPPORT SYSTEM FOR PALM PLANTATION LAND SELECTION USING THE TOPSIS METHOD

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Abstract—Palm oil is an important export commodity in Indonesia. Quality palm oil is produced from quality oil palm plants as well. One of the factors to make quality oil palm plantations requires suitable land. For this reason, the land selection is an essential factor. This study aims to develop a decision support system by implementing the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method for selecting oil palm plantations. The TOPSIS method is a negative approach that considers the shortest distance from the positive ideal solution and the farthest from the perfect solution. System development uses a waterfall system development approach that begins with analysis, design, coding, and testing. The developed method can manage alternatives, manage criteria, perform alternative calculations with TOPSIS, and display the best alternative results with TOPSIS. The results of the black-box testing process show that the developed system can work and run well. In addition, the results of manual calculations with the system show the same results.

Keywords: Decision support system, oil palm land, TOPSIS.

Abstrak—Minyak sawit merupakan komoditi ekspor penting di Indonesia. Minyak kelapa sawit yang berkualitas dihasilkan dari tanaman kelapa sawit yang berkualitas juga. Salah satu faktor untuk dapat menghasilkan tanaman sawit yang berkualitas maka dibutuhkan lahan yang tepat. Untuk itu pemilihan lahan menjadi salah satu faktor penting. Penelitian ini bertujuan untuk mengembangkan sistem pendukung keputusan dengan mengimplementasikan metode Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) untuk pemilihan lahan tanaman sawit. Metode TOPSIS merupakan pendekatan yang solusi

didapatkan atas pertimbangan jarak terpendek dari solusi ideal positif dan terjauh dari solusi ideal negatif. Sistem dibangun menggunakan pendekatan pengembangan sistem waterfall yang dimulai dari analisis, desain, pengkodean dan pengujian. Sistem yang dikembangkan memiliki kemampuan mengelola alternatif, mengelola kriteria, melakukan perhitungan alternatif dengan TOPSIS, dan menampilkan hasil alternatif terbaik dengan TOPSIS. Dari hasil pengujian black-box testing memperlihatkan bahwa sistem yang dikembangkan dapat berfungsi dan berjalan dengan baik. Selain itu hasil perhitungan manual dengan sistem menunjukkan hasil yang sama.

Kata Kunci: sistem pendukung keputusan, lahan kelapa sawit, TOPSIS.

INTRODUCTION

Palm oil is a commodity that has a vital role in building the economy in Indonesia. Data shows that Indonesia is the world's largest exporter of palm oil (Purba & Sipayung, 2017). According to data from the Ministry of Agriculture of the Republic of Indonesia, the total value of palm oil exports from Indonesia will reach US\$17.36 billion in 2020. Currently, Indonesian and Malaysian palm oil smallholders meet 85-90% of total global palm oil production (Firnando & Kurniawan, 2020). However, the quality of oil palm production is affected by the area of oil palm (Dianto, Efendi, & Wachjar, 2017). Fertile land is essential for creating good quality oil palm for good land criteria based on land sample data such as rainfall, topography, slopes, water depth, and texture (Dianto et al., 2017). An automatic selection system is needed to make it easier and provide solutions for land users in helping the selection of the best land.

Seeing from these problems, it will be easier if there is a system that can help overcome or minimize the pain of land selection. The process of selecting oil palm plantations can use a decision support system. Decision support systems can manage information, model, and manipulate data to support decision-making (Fernando & Fernanda, 2017)(Samsudin, 2018). Use several methods to build a decision support system, including Decision Tree, Group Technology, Multiple Criteria Decision Making (MCDM), and others. MCDM has a goal to choose the best alternative from several available options and then mutually benefit based on the performance of each choice against the criteria set by the decision-maker (Borman, Mayangsari, & Muslihudin, 2018). One MCDM algorithm that produces the best alternative ranking is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. The TOPSIS method is an approach that applies the principle of choosing an alternative if it has the shortest distance from the positive ideal solution and the farthest from the perfect negative solution to get the optimal solution. (Nurelasari & Purwaningsih, 2020). The TOPSIS method has advantages: ease of implementation because of the simple concept, efficient computation, and the resulting solution at a distance between the positive and negative ideal solutions (Hertyana, 2019).

Previous studies have shown that the TOPSIS method has a good level of accuracy. In research on using the MCDM algorithm with the TOPSIS method in selecting robusta coffee beans with export quality value, the accuracy rate reaches 84% (Borman, Megawaty, & Attohiroh, 2020). This study shows that the TOPSIS method is simple and can produce the best alternative based on the shortest distance from the positive ideal solution and the furthest from the perfect negative solution, thus producing a more accurate answer. Another study regarding implementing the TOPSIS method for a location-based tourist spot recommendation system in Malang with an accuracy value of 83.3% (Paypas, Dewi, & Brata, 2019). This study used TOPSIS to obtain ranking priorities based on the assessment criteria.

This study aims to build and develop a decision support system by implementing the TOPSIS method for the selection of oil palm plantations to assist and facilitate companies engaged in the management of oil palm plantations so that rankings or the final results of selecting the best oil palm land and producing optimal palm oil production. The land criteria used by the Department of Agriculture and Plantation include rainfall, topography, slopes, water depth, and texture.

MATERIALS AND METHODS

This research consists of several stages, which refer to the Waterfall system development model stages. The Waterfall approach has sequential software development stages, namely stages from analysis, design, coding, and testing. (Irnawati, 2017). Research stages are activities carried out in a planned, regular, and systematic way to achieve specific goals (Borman, Yasin, et al., 2020). The stages of the research see in Figure 1.

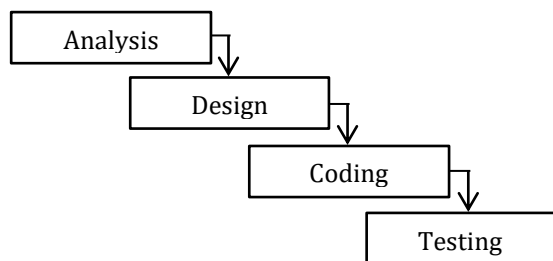


Figure 1. Research Stages

A. Analysis

The analysis stage begins with problem identification analysis effect of oil palm production quality by oil palm land. Fertile land is an essential element for creating good quality oil palm. Solving these problems develops a decision support system. The decision support system uses the TOPSIS method in this study.

B. Design

After the analysis, design a design based on the solutions offered from the analysis results. At this stage, do the modelling to develop the system. In this study, the method uses use case diagrams. Use case diagrams to describe the interaction between one or more actors and the system to be developed (Melinda, Borman, & Susanto, 2018). Use case diagrams to illustrate the expected functionality of a system (Borman & Fauzi, 2018). The use case diagram of the system to be developed see in Figure 2.

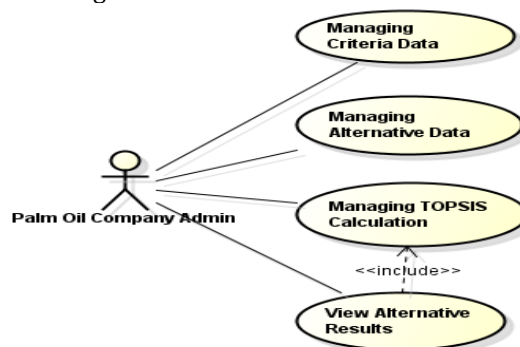


Figure 2. Use Case Diagram of The Developed System

C. Coding

At this stage, the implementation applies how the system works based on the results of the analysis and designs that have been made previously into a particular programming language to become later an application (Saputra & Borman, 2020). In this research, the web-based system for the programming language used is PHP and uses a MySQL database.

D. Testing

After coding the application, it needs testing, and this aims to find out whether the software has worked well (Nugroho, Handayani, Destriana, & Ernawati, 2021). For that, at this stage will be tested by testing the system's functionality using black-box testing.

RESULTS AND DISCUSSION

The main problem of this research is how to select the best land for oil palm plantations. Fertile land is an essential element for creating quality oil palms. Develop a decision support system using the TOPSIS method, starting with determining the criteria. The Plantation Office of Lampung Province determines the criteria to determine the requirements, including rainfall, topography, slope, water depth, and texture. Quality scores on each measure such as Good (8 to 10), Fairly Good (6 to 7), Poor (3 to 5), and Very Poor (0 to 2). The score is the conversion value of the quality value of each criterion. The table of criteria for selecting oil palm land is in Table 1.

Table 1. Criteria for Selection of Oil Palm Land

No	Criteria Id	Criteria	Quality Value	Value
1	C1	Rainfall(mm)	>1600	0-2
			1601-1800	3-5
			1801-2000	6-7
			2001-2500	8-10
2	C2	Topography	Steep	0-2
			Hilly	3-5
			Wavy	6-7
			Flat	8-10
3	C3	Slope (%)	>36	0-2
			25-36	3-5
			16-24	6-7
			0-15	8-10
4	C4	Water Depth(cm)	40-50	0-2
			51-60	3-5
			61-80	6-7
			>80	8-10
5	C5	Texture	Sand	0-2
			Sandy Loam	3-5
			Sandy clay	6-7
			Clay	8-10

After determining the criteria, they then choose the weight value used for assessing each alternative obtained from the decision-maker. The

weighted value consists of a value of 1 to 5, with weights: Very Important (5); Important (4); Quite Important (3); Not Important (2); Very Unimportant (1). The preference weights obtained from the decision-makers for each criterion see in table 2.

Table 2. Criteria Weight

C1	C2	C3	C4	C5
5	3	4	3	4

The use of the TOPSIS method in the selection of oil palm land uses four alternatives, namely: Merak Batin Village Land (A1); Margo Harjo Village Land (A2), Bumi Rahayu Village Land (A3); Tentrem Village Land (A4). The results of the assessment of these alternatives based on predetermined criteria can see in table 3.

Table 3. Alternative Values on Each Criterion

Alternative ID	Criteria				
	C1	C2	C3	C4	C5
A1	8	8	4	8	6
A2	9	6	5	7	8
A3	8	8	4	7	8
A4	7	6	3	8	7

From these cases to the completion of the TOPSIS method through several stages. Here are the steps to solving it.

1. Determine the normalized decision matrix

Determination of performance for each alternative, a normalized decision matrix is needed. The normalized decision matrix for each criterion (Xij) is obtained from all other options and divided by the number of bars on each measure. To calculate the normalized decision matrix, one can use equation (1).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \dots \dots \dots (1)$$

where:

r_{ij}= result of normalized decision matrix (R matrix)
 i= 1,2,...,m and j= 1,2,...,n

From alternative values in Table 3, the calculation of the normalization decision matrix is as follows:

$$r_{11} = 0.4981$$

$$r_{21} = 0.5603$$

$$r_{31} = 0.4981$$

$$r_{41} = 0.4358$$

And so on until all alternative values on each criterion are normalized. The following is the result of the normalized decision matrix calculation:

$$R = \begin{bmatrix} 0.4981 & 0.5657 & 0.4924 & 0.5322 & 0.4111 \\ 0.5603 & 0.4243 & 0.6155 & 0.4656 & 0.5482 \\ 0.4981 & 0.5657 & 0.4924 & 0.4656 & 0.5482 \\ 0.4358 & 0.4243 & 0.3693 & 0.5322 & 0.4796 \end{bmatrix}$$

2. Determine the weighted normalized decision matrix

Create a weighted normalized decision matrix with weight $W = (w_1, w_2, \dots, w_n)$.

$$Y = \begin{bmatrix} w_{11}r_{11} & \dots & w_{1n}r_{1n} \\ \dots & \dots & \dots \\ w_{m1}r_{m1} & \dots & w_{nm}r_{nm} \end{bmatrix} \dots \dots \dots (2)$$

Based on table 2, the weight of the criteria $W = (5,3,4,3,4)$, weighted normalized matrix using equation 2:

$$\begin{aligned} y_{11} &= w_1 r_{11} = 2.4903 \\ y_{21} &= w_1 r_{21} = 2.8016 \\ y_{31} &= w_1 r_{31} = 2.4903 \\ y_{41} &= w_1 r_{41} = 2.1790 \end{aligned}$$

And so on until all R values are multiplied by their weights. So that the weighted normalization decision matrix (Matrix Y) is as follows:

$$Y = \begin{bmatrix} 2,4903 & 1,6971 & 1,9695 & 1,5965 & 1,6445 \\ 2,8016 & 1,2728 & 2,4618 & 1,3969 & 2,1926 \\ 2,4903 & 1,6971 & 1,9695 & 1,3969 & 2,1926 \\ 2,1790 & 1,2728 & 1,4771 & 1,5965 & 1,9185 \end{bmatrix}$$

3. Determine the positive ideal solution matrix and negative ideal solution.

Determine the positive and negative ideal solutions using equations (3) and (4).

$$A^+ = y_1^+, y_2^+, \dots, y_n^+ \dots \dots \dots (3)$$

$$A^- = y_1^-, y_2^-, \dots, y_n^- \dots \dots \dots (4)$$

with,

$$y_j^+ = \begin{cases} \max_i y_{ij} ; \text{ If } j \text{ is a benefit attribute} \\ i \\ \min_i y_{ij} ; \text{ If } j \text{ is a benefit cost} \\ i \end{cases}$$

$$y_j^- = \begin{cases} \min_i y_{ij} ; \text{ If } j \text{ is a benefit attribute} \\ i \\ \max_i y_{ij} ; \text{ If } j \text{ is a benefit cost} \\ i \end{cases}$$

where, $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$

Positive ideal solution matrix using equations (3) and (4):

$$\begin{aligned} y_1^+ &= 2.8016 \\ y_2^+ &= 1.6971 \\ y_3^+ &= 1.4771 \\ y_4^+ &= 1.5965 \\ y_5^+ &= 2.1926 \\ A^+ &= \{2.8016; 1.6971; 1.4771; 1.5965; 2.1926\} \end{aligned}$$

While calculating the negative ideal solution matrix with the following details:

$$\begin{aligned} y_1^- &= 2.1790 \\ y_2^- &= 1.2728 \\ y_3^- &= 2.4618 \\ y_4^- &= 1.3969 \\ y_5^- &= 1.6445 \\ A^- &= \{2.1790; 1.2728; 2.4618; 1.3969; 1.6445\} \end{aligned}$$

4. Determine the distance between the values of each alternative with the positive ideal solution matrix and the negative ideal solution matrix.

To determine the distance between the values for each alternative with a positive ideal solution matrix and a negative ideal solution matrix. Determine the length using equations (5) and (6).

$$D_i^+ = \sqrt{\sum_{j=1}^n (y_{ij} - y_j^+)^2} \dots \dots \dots (5)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (y_{ij} - y_j^-)^2} \dots \dots \dots (6)$$

where, $i = 1, 2, \dots, m$

From this equation, the positive ideal solution distance is as follows:

$$\begin{aligned} D_1^+ &= 0.7999 \\ D_2^+ &= 1.0907 \\ D_3^+ &= 0.6157 \\ D_4^+ &= 0.8017 \end{aligned}$$

While the negative ideal solution distance is as follows:

$$\begin{aligned} D_1^- &= 0.7478 \\ D_2^- &= 0.8295 \\ D_3^- &= 0.9054 \\ D_4^- &= 1.0415 \end{aligned}$$

5. Determine the preference value for each alternative

Preference for each option calculates via equation (7).

$$V_i = \frac{D_i^-}{D_i^- + D_i^+} \dots \dots \dots (7)$$

where, $i = 1, 2, \dots, m$

From equation (7), the value of each preference is as follows:

$$\begin{aligned} V_1 &= 0.483164724 \\ V_2 &= 0.431996547 \\ V_3 &= 0.595214512 \\ V_4 &= 0.565041943 \end{aligned}$$

A more considerable V_i value indicates that alternative V_i is the best. So from the results of the preference values for each alternative, a ranking is

made from the highest value to the lowest value, as in table 7.

Table 4. Preference Ranking Value of Each Alternative

Alternative	Preference Value
Bumi Rahayu Village Land (A3)	0,595214512
Tentrem Village Land (A4)	0,565041943
Merak Batin Village Land (A1)	0,483164724
Margo Harjo Village Land (A2)	0,431996547

Furthermore, the TOPSIS method is applied in the form of an application. Figure 3 shows the main page view of the web-based decision support system for implementing oil palm land selection.



Figure 3. Main Page of The System Being Developed

In the decision support system developed, the user, in this case, is the admin of an oil palm management company who will look for land to plant oil palm, can manage criteria, manage alternatives, manage matrix values, and can see the best alternative results using TOPSIS. In the criteria menu, users can manage standards by adding and deleting criteria and giving weight to each bar. The criteria menu display see in Figure 4.

Criteria ID	Criteria Name	Weight	Status	Action
1	Rainfall	5	Benefit	<input checked="" type="checkbox"/> <input type="checkbox"/>
2	Topography	3	Benefit	<input checked="" type="checkbox"/> <input type="checkbox"/>
3	Slope	4	Cost	<input checked="" type="checkbox"/> <input type="checkbox"/>
4	Water Depth	3	Benefit	<input checked="" type="checkbox"/> <input type="checkbox"/>
5	Texture	4	Benefit	<input checked="" type="checkbox"/> <input type="checkbox"/>

Figure 4. Managing Criteria

Meanwhile, to manage alternatives, users can enter the alternative menu. In this menu, the user can add alternatives and delete alternatives. Furthermore, the user can provide a value for each alternative against the criteria in the matrix value menu. In the TOPSIS results menu, the user can see

the calculation results and the best alternative. The results of the TOPSIS calculation on the system see in Figure 5.

No	Alternatif	Nama	V _i
1	A1	Merak Batin Village Land	0.48317074746431
2	A2	Margo Harjo Village Land	0.43201583085976
3	A3	Bumi Rahayu Village Land	0.59528035233024
4	A4	Tentrem Village Land	0.56507350946672

Figure 5. Results of Preference Values

After implementing the application, then testing the system. Black Box as a tool to test every feature on this system. The results of the Black-box testing see in table 5.

Table 5. Test Results Black-Box Testing

No	Tested features	Expected results	Conclusion
1	Main Menu	Can display the main menu	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
2	Displaying Criteria	Can display criteria menu	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
3	Adding Criteria	Can add criteria	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
4	Deleting Criteria	Can delete criteria	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
5	Displaying Alternative	Can display alternative menu	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
6	Adding Alternative	Can add alternative	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
7	Deleting Alternative	Can delete alternative	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
8	Show alternative values	Can display the value of each alternative	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
9	Adding alternative value	Can add alternative value	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
10	Removing alternative values	Can delete alternative values	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail
11	Displaying TOPSIS Calculation Results	Can display TOPSIS calculation results	(<input checked="" type="checkbox"/>) pass (<input type="checkbox"/>) fail

The test results show that the system can function properly and the calculation results of the TOPSIS method manually, and what the system produces is appropriate.

CONCLUSION

This study resulted in a decision support system for selecting oil palm land using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. The TOPSIS method can produce the best alternative based on the shortest distance from the positive ideal solution and the farthest from the perfect negative solution. The developed system can manage options, and criteria, perform alternative calculations with TOPSIS and display the best alternative results with TOPSIS. The results of black-box testing show that the developed system can function and run well. In addition, the results of manual calculations with the system show the same results.

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