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Decision Support System for Determining the Suitability of Vegetable Cultivation Using the Multifactor Evaluation Process Method

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Abstract: *The challenge faced by farmers today is that it is still difficult to determine the types of vegetable crops that are suitable for cultivation according to environmental conditions, namely climate, soil type, and water requirements. Inaccuracies in choosing crop types are often caused by limited knowledge and lack of access to information related to the influence of environmental factors on the success of cultivation. This constraint makes it difficult for farmers to identify the characteristics of the selection of commodity types of vegetable crops that should be cultivated, this has an impact on suboptimal yields and limited sustainability in agriculture. Decision Support System (DSS) technology can help overcome this problem with its ability to determine the suitability of vegetable cultivation. The Multifactor Evaluation Process (MFEP) method is used in this study to assess and rank alternatives based on criteria that have been given weight values based on the parameters of temperature, sunlight, rainfall, humidity, slope, soil pH, and altitude. The results of the application of the MFEP method show that the system can provide recommendations based on validation testing accuracy values reaching 81.8%, precision 100%, recall 71.4%, specificity 100%, and f1-score 83.3%. These results show that DSS using the MFEP method can provide relevant recommendations by assisting farmers in choosing the type of vegetable crops that best suit the environmental conditions in their area. The benefits of this research can facilitate farmers in recommending types of vegetable crops that are suitable for cultivation to increase productivity and quality of crops.*

Keywords: *Decision Support System, Recommendation System, Multifactor Evaluation Process, Suitability of Vegetable Cultivation.*

1. Introduction

Advances in information technology are increasingly sophisticated and rapid, enabling access to information from anywhere via the Internet. Information technology has been widely adopted and embraced by most people because it offers tremendous benefits. Information technology is an integral part of people's daily lives. It has been used in various fields, including agriculture, where it can be utilised by farmers, such as in vegetable cultivation [1]. Innovation in technology plays an important role in management and decision-making, including in agriculture [2]. With this innovation, farmers can more easily manage their land and determine the best steps in vegetable cultivation. Demand for vegetables in Indonesia continues to grow, driven by rising public awareness of healthy eating and balanced nutrition [3]. Vegetable plants are seasonal, multicellular, eukaryotic organisms that make their own food through photosynthesis. Vegetable crops usually have a short lifespan, less than one year. Losses also often occur to farmers in the cultivation of these vegetable crops. One of the causes of these losses is several factors related to natural and environmental conditions [4].

The problem this study addresses is that farmers have difficulty selecting suitable vegetable crops based on environmental conditions. Based on interviews with farmer groups from the *Kawasan Rumah Pangan Lestari* (KRPL) in the Gunung Menur Hamlet area, Bawean, it was found that farmers often experience a 20–30% decline in crop yields due to planting unsuitable crop varieties for local environmental conditions. This farmer group also experienced crop failures when cultivating vegetables such as broccoli and chicory, due to various environmental factors affecting plant growth and a lack of knowledge and access to relevant information. Therefore, the use of advanced technologies, such as Decision Support Systems (DSS), is needed to assist farmers in obtaining recommendations for suitable vegetable crop types based on environmental conditions, thereby achieving optimal yields.

Based on previous research, studies [3][4] have used the Analytic Hierarchy Process (AHP) method. Researcher [3] applied the AHP approach, using parameters such as sunlight, altitude, rainfall, and soil reaction (pH), combined with the User Acceptance Test (UAT) method, achieving an accuracy rate of 85%. Furthermore, researcher [4] used parameters including land height, average temperature, soil type, rainfall, and effective soil depth, combined with the System Usability Scale (SU, and achieved an accuracy of 86.41%. Meanwhile, researchers [5] implemented the Multi-Objective Optimization based on Ratio Analysis (MOORA) combined with the System Usability Scale (SUS) method, using parameters such as temperature, rainfall, relative humidity (RH), texture, drainage, pH, effective depth, slope, and inundation, achieving an accuracy value of 91%. From these studies, it can be concluded that no prior research has used the Multifactor Evaluation Process (MFEP) method to determine the suitability of vegetable cultivation. This study, therefore, uses seven parameters as evaluation criteria: temperature, sunlight, rainfall, humidity, soil pH, slope, and altitude. The novelty of this research lies in the use of the MFEP method as a decision-support model in the agricultural sector, where its application remains very limited. The MFEP approach provides a simpler yet reliable way to evaluate multiple environmental factors simultaneously through weighted parameter analysis. By implementing MFEP, this research aims to improve the accuracy and practicality of decision-support systems for farmers, especially in tropical regions where environmental variability greatly influences agricultural productivity.

The purpose of this research is to develop a decision support system for determining the suitability of vegetable cultivation using the MFEP method. The system is designed based on seven environmental parameters, namely temperature, sunlight, rainfall, humidity, soil pH, slope, and altitude. The MFEP method is applied as a weighting mechanism to evaluate multiple factors that influence crop suitability and to quantify the importance of each criterion in the decision-making process [6]. Through this approach, the system can analyse environmental conditions such as humidity and harvest period, display data on criteria, sub-criteria, and alternatives, and generate a ranking report recommending the most suitable vegetable crops based on environmental conditions.

2. Research Method

The research method used is the Figure 1 process algorithm, based on the MFEP method, to assess and rank alternatives according to each criterion, using assigned weight values. In the initial stage, namely, entering the criteria data, the system will determine the criteria's weighting, which is set to 1. If the weight is less than 1, it will proceed to the weighting results for the criteria; if more than 1, it will return to data entry. The factor values for each criterion will be used in the weight calculation process. The total evaluation value is then calculated to obtain the ranking value, and finally, the ranking results recommending vegetable crops are displayed. The research method process model in Figure 1 is used to make decisions based on a weighting system and evaluation of criteria in determining the suitability of vegetable crops to environmental conditions:

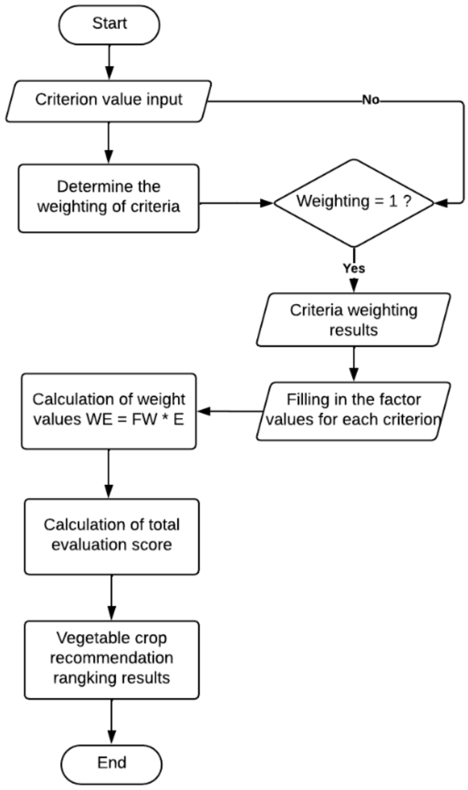

Figure 1: Research Method Process Model

1) Criterion Value Input: The criteria used as parameters in determining the suitability of vegetable cultivation are listed in Table 1.

Table 1. Criteria

Code	Criteria
C1	Temperature
C2	Sunlight
C3	Rainfall
C4	Humidity
C5	Soil pH
C6	Slope
C7	Altitude

These parameters represent the main environmental factors that influence crop growth and productivity. Environmental data were obtained from two sources:

- Primary data, collected through direct field observation in *Gunung Menur Hamlet, Bawean Island,* using a thermometer.
- Secondary data, collected from the BMKG

2) Determination of criteria weights: each criterion is given a weight listed in Table 2 and calculated using Equation (1). The weighting process is based on the relative importance of each environmental factor, ensuring that the total weight of all criteria equals 1.

3) Factor assessment: each factor is assigned a score on the suitability scale, ranging from 1 to 4, where a higher score indicates a greater suitability of the environmental condition for vegetable cultivation.

4) Rating value: The factor scores are determined from field data to evaluate the degree of suitability of each criterion to the environmental conditions of the study area. This evaluation was conducted using field data collected from *Gunung Menur Hamlet, Bawean Island,* to represent real cultivation conditions.

5) Calculation of weight value: the weighted value of each criterion is obtained by multiplying the factor score by its corresponding criterion weight using Equation (2).

6) Calculation of total evaluation: the total evaluation score for each is obtained by summing the weighted values of all criteria using Equation (3). This calculation produces a composite value that reflects the overall suitability level of each vegetable crop with the environmental parameters.

7) Ranking of alternatives: The final step is to determine the ranking of vegetable alternatives based on the total evaluation scores. The vegetable alternative with the highest total score is considered the most suitable for cultivation under the given environmental conditions.

2.1. Metode *Multifactor Evaluation Process* (MFEP)

The Multifactor Evaluation Process (MFEP) is a weight-based quantitative approach in which decision makers subjectively and intuitively assess the factors that significantly affect their choice [7]. This method is popular due to its simple, easy-to-understand concept, efficient computation, and ability to measure relative performance and decision alternatives in a straightforward mathematical way [8]. The MFEP method is a crucial technique used in developing approaches to decision support systems [9]. In its application, the MFEP method emphasises various aspects and criteria in the assessment process, while fulfilling the calculation of the weighting system. Nonetheless, the calculations serve as a guide for assessing each aspect based on the available information[10].

In the calculation process, the MFEP method can be applied by calculating the weight of the factor evaluation using Equation (1), where the *EF* variable is the factor evaluation, the *x* variable is the sub-criteria value, and $\sum_{x\,Max}$ maximum value of *x*.

$$EF= \frac{\sum x}{\sum x\,Max} \tag{1}$$

The evaluation weight is determined using Equation (2), where WE is the evaluation weight, FW is the factor weight, and *E* is the factor evaluation value.

$$WE= FW * E \tag{2}$$

The total overall evaluation score is obtained by summing all individual evaluation weights according to Equation (3), where WE_i is the evaluation weight for the *i*-th component, while the sum result shows the total value of all evaluation weights [11].

$$\sum_i^n = WE_i = WE_1 + WE_2 + WE_n \tag{3}$$

2.2. Model Evaluation

The model evaluation in the study uses the Confusion Matrix as a simple and effective method to assess classifier performance, with the main advantage being its ease of interpretation. A confusion matrix consists of four main categories: True Positive (TP), False Positive (FP), False Negative (FN), and True Negative (TN) [12]. This matrix presents the number of correct test results and errors, making it easier to analyse the model's performance in a more structured manner [13]. TP occurs when the model correctly identifies a positive case, while TN indicates that the prediction and the actual outcome are both negative. FP occurs when the model predicts a positive outcome when it is negative, while FN occurs when the model misclassifies a positive case as negative [14]. Equations (4)-(7) are the values of accuracy, precision, recall, specificity, and f1-score [15]:

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \tag{4}$$

$$\text{Precision} = \frac{TP}{TP+FP} \tag{5}$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad (6)$$

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (7)$$

$$\text{F1-score} = 2\,x\,\frac{PrecisionxRecall}{Precision+Recall} \quad (8)$$

By utilising a confusion matrix, the validation process evaluates the algorithm's performance using accuracy, precision, recall, specificity, and F1-score. The purpose of this process is to assess the effectiveness of the reasoning used [16]. In addition, by using a modified confusion matrix from categorisation, model evaluation can be performed more easily and consistently. In some cases, certain measures are more important than others, so the choice of the confusion matrix should be tailored to the analysis's needs [17].

2.3. System Architecture

The system architecture illustrates the overall workflow of the proposed recommendation system and how its components interact. In this system, the admin is responsible for inputting environmental criteria data, including temperature, sunlight, rainfall, humidity, soil pH, slope, and altitude. All data is stored in the database.

Furthermore, the user (farmer) inputs alternative data on vegetable types. The system then processes this data using the MFEP method, assigning weights to each criterion and evaluating each alternative to produce a ranking. Finally, the system generates and displays recommendations for the most suitable vegetable crops based on the given environmental conditions. The system architecture is shown in Figure 2.

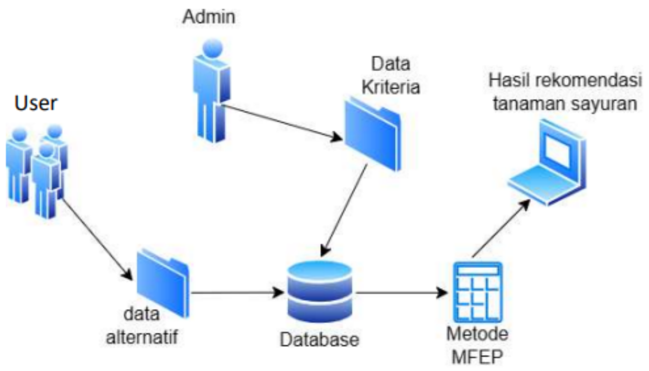

Figure 2. System Architecture

3. Results and Discussion

The Implementation of the Multifactor Evaluation Process (MFEP) method in this study involves calculating the weight of each criterion and evaluating alternative vegetable crops based on environmental parameters. The weighting process considers the level of influence each factor has on crop growth, with the total weight normalised to ensure the sum equals 1. The weight of each criterion is presented in Table 2.

Table 2. Criteria Weight Value

Code	Criteria	Weight
C1	Temperature	0.25
C2	Sunlight	0.20
C3	Rainfall	0.15
C4	Humidity	0.10

Code	Criteria	Weight
C5	Soil pH	0.10
C6	Slope	0.10
C7	Altitude	0.10

Based on Table 2, temperature has the highest weight of 0.25, indicating that it plays a dominant role in determining crop suitability. Sunlight and rainfall follow with weights of 0.20 and 0.15, respectively, as they significantly affect photosynthesis and water availability. Other factors, such as humidity, soil pH, slope, and altitude, are assigned equal weights of 0.10. The sub-criteria values used in this study are shown in Table 3.

Table 3. Sub Criteria Values

Code	Criteria	Parameters	Value
C1	Temperature	20-25°C	4
		26-31°C	3
		32-37°C	2
		>37°C	1
C2	Sunlight	Full	3
		Medium	2
		Obstructed	1
C3	Rainfall	High	3
		Medium	2
		Low	1
C4	Humidity	24-44%	4
		45-65%	3
		66-86%	2
		≥87 %	1
C5	Soil pH	<7	3
		7	2
		>7	1
C6	Slope	<20%	4
		≥20% - <40	3
		≥40% - <60%	2
		≥60%	1
C7	Altitude	0-500 mdpl	4
		500-1500 mdpl	3
		1500-3000 mdpl	2
		>3000 mdpl	1

These values represent the level of suitability for each environmental parameter. Higher values indicate better suitability for vegetable cultivation under specific environmental conditions. The vegetable crop alternatives analysed in this study are listed in Table 4.

Table 4. Alternative

Code	Alternative
A1	Lettuce
A2	Aubergine
A3	Water flask
A4	Bitter melon
A5	Tomato
A6	Leeks

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Code	Alternative
A7	Celery
A8	Chili
A9	Mustard
A10	Kale
A11	Cucumber
A12	Long beans

Each alternative is coded to simplify the evaluation process and facilitate ranking. The suitability rating for each alternative, based on the criteria, is shown in Table 5.

Table 5. Suitability Rating of Alternative

Alternative	Criteria						
	C1	C2	C3	C4	C5	C6	C7
A1	4	2	2	2	3	4	4
A2	3	3	1	3	3	4	4
A3	3	3	1	3	3	4	4
A4	3	3	1	3	3	4	4
A5	3	3	1	3	3	4	4
A6	4	2	2	2	3	4	4
A7	4	2	2	2	3	4	4
A8	3	3	1	3	3	4	4
A9	4	2	2	2	3	4	4
A10	4	2	2	2	3	4	4
A11	3	3	1	2	3	4	4
A12	3	3	1	3	3	4	4

The MFEP calculation is carried out by multiplying each criterion weight by its corresponding suitability value. An example of the calculation for alternative A1 is as follows:

$$WE_{A1} = (0.25 \times 4) + (0{,}20 \times 2) + (0{,}15 \times 2) + (0{,}10 \times 2) + (0{,}10 \times 3) + (0{,}10 \times 4) + (0{,}10 \times 4) = 1 + 0{,}4 + 0{,}3 + 0{,}2 + 0{,}3 + 0{,}4 + 0{,}4 = 3$$

The same calculation process is applied to all alternatives to obtain the final ranking results. The evaluation results indicate that several alternatives, including lettuce (A1), leeks (A6), celery (A7), mustard (A9), and kale (A10), achieved the highest score of 3. This indicates that these crops are well-suited to cultivation under the observed environmental conditions. The ranking results of the alternatives are presented in Table 6.

Table 6. Ranking

Code	Alternative Name	Total	Rank
A1	Lettuce	3	1
A6	Leeks	3	2
A7	Celery	3	3
A9	Mustard	3	4
A10	Kale	3	5
A2	Aubergine	2,9	6
A3	Water flask	2,9	7
A4	Bitter melon	2,9	8
A5	Tomato	2,9	9
A8	Chili	2,9	10
A12	Long beans	2,9	11
A11	Cucumber	2,8	12

Based on Table 6, lettuce (A1) ranks first, indicating that it is the most suitable vegetable crop under the given environmental conditions. The ranking results demonstrate that the MFEP method provides consistent, reliable recommendations based on the assigned weights and environmental criteria. Alternatives with the highest scores are highly suitable, while those with lower scores still meet the minimum cultivation requirements.

To further evaluate the performance of the proposed system, a validation process is conducted using a confusion matrix. This evaluation aims to assess how accurately the system classifies crops as suitable or unsuitable according to predefined criteria. The performance evaluation results are presented in Table 7.

Table 7. Confusion Matrix

		Prediction	
		True (T)	**False (F)**
Actual	Positif (P)	5	0
	Negative (N)	4	2

The evaluation results for the decision support system's suitability assessment of vegetable cultivation using the MFEP method are based on the confusion matrix shown in Table 7. Equations calculate the value of accuracy, precision, recall, and F1-Score (4) to (7), respectively.

$$\text{Accuracy} = \frac{5+4}{5+4+0+2} = \frac{9}{10} \times 100\% = 81{,}8\%$$

$$\text{Precision} = \frac{5}{5+0} = \frac{5}{5} \times 100\% = 100\%$$

$$\text{Recall} = \frac{5}{5+2} = \frac{5}{7} \times 100\% = 71.4\%$$

$$\text{Specificity} = \frac{4}{4+10} = \frac{4}{4} \times 100\% = 100\%$$

$$\text{F1} - \text{score} = 2 \times \frac{100\% \times 71.4\%}{100\% \times 71.4\%} \times 100\% = 83.3\%$$

Based on the calculation, the system achieves an accuracy of 81.8%, indicating that most of its predictions are correct. The precision value reaches 100%, showing that all crops classified as suitable are indeed relevant and appropriate. However, the recall value of 71.4% indicates that the system failed to identify some suitable crops.

Furthermore, the specificity value of 100% indicates that the system is highly effective in correctly identifying unsuitable crops. The F1-score, which balances precision and recall, is 83.3%, indicating the system's overall good performance. These results demonstrate that the proposed system provides accurate and reliable recommendations for vegetable crop suitability.

3.1 Discussion

From a discussion perspective, the high precision value indicates that all recommended crops are relevant to the environmental conditions. However, the lower recall suggests that there is still room to improve in identifying all suitable crop alternatives. This indicates that while the system is highly accurate in its recommendations, it may not yet capture all possible relevant options.

When compared with previous studies, this research demonstrates competitive performance. Studies using the AHP method reported an accuracy of 85% [3], Profile Matching achieved 86.41% [4], and MOORA reached 91% [5]. Although the accuracy obtained in this study is slightly lower, the MFEP method offers advantages in terms of simplicity and ease of implementation. Unlike more complex methods, MFEP provides a straightforward weighting mechanism that is easier to apply, especially for users with limited technical expertise.

Another important contribution of this study is the use of seven environmental parameters, which provide a more comprehensive evaluation than previous studies that used fewer criteria. In addition, the integration of a confusion matrix strengthens the reliability of the system in measuring its performance quantitatively.

The findings of this study have practical implications for agricultural decision-making. By providing accurate, relevant recommendations, the system can help farmers select appropriate vegetable crops, thereby reducing the risk of crop failure and improving productivity. Moreover, the system can be further developed by integrating real-time environmental data to enhance adaptability under changing climate conditions.

4. Conclusions

This study successfully developed a decision-support system for assessing the suitability of vegetable cultivation using the MFEP method. The system assists farmers in selecting appropriate vegetable crops based on environmental criteria, including temperature, sunlight, rainfall, humidity, soil pH, slope, and altitude.

The evaluation results show that the system achieves an accuracy of 81.8%, precision of 100%, recall of 71.4%, and an F1-score of 83.3%. These results indicate that the proposed system can provide accurate and reliable recommendations for selecting vegetable crops under specific environmental conditions.

For future development, the system can be improved by incorporating additional factors such as soil type, irrigation availability, and pest and disease potential. Furthermore, integrating IoT technology for real-time environmental monitoring may enhance the system's accuracy and effectiveness in supporting agricultural decision-making.

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