Volume 4 No. 2 (July - December 2024), pp. 100-112 | ISSN 2962-2360 (online) | ISSN 2962-3669 (print)
Arcitech: Journal of Computer Science and Artificial Intelligence
https://journal.iaincurup.ac.id/index.php/arcitech/article/view/11957 | DOI : https://dx.doi.org/10.29240/arcitech.v4i2.11957

# Decision Support System for Plantation Land Suitability Assessment Using A Combination of AHP (Analytical Hierarchy Process) and Profile Matching Method

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## Article Information

### Article history

Received December 20, 2024
Revised December 25, 2024
Accepted December 26, 2024
Available December 30, 2024

## Keywords

Decision Support System
Agriculture
Plantation
Land Suitability
Profile Matching
Analytic Hierarchy Process

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## Abstract

Determining the suitability of plantation land is a crucial factor in enhancing productivity and sustainability in the agricultural sector. However, existing studies often lack comprehensive approaches that integrate both the prioritization of criteria and precise evaluation of land suitability. This study addresses this gap by developing a decision support system (DSS) for plantation land suitability using a combination of the Profile Matching and Analytic Hierarchy Process (AHP) methods. The AHP method is employed to assign weights to various criteria based on their relative importance, while the Profile Matching method evaluates land suitability based on the generated profiles. The results indicate that this integrated approach provides accurate and detailed land suitability recommendations. Specifically, Buket Rata land is suitable for Clove (preference score: 3.821), Oil Palm, and Tea (3.596); Reulet land is suitable for Cocoa (3.22) and Coconut (3.16); Geulanggang Kulam land is suitable for Clove (3.41), Cocoa (3.35), and Oil Palm (3.29); Sawang land is suitable for Clove (3.41), Oil Palm (3.17), and Cocoa (2.99); and Pesisir Laut land is suitable for Sugarcane (3.353) and Clove (3.173). This DSS not only aids decision-makers in optimizing land use and managing sustainable plantations but also contributes to the broader field of agricultural decision-making by demonstrating the effectiveness of combining AHP and Profile Matching methods.

**Keywords** : *Decision Support System, Agriculture, Plantation, Land Suitability, Profile Matching, Analytic Hierarchy Process*



## 1. Introduction

Plantations play a crucial role in supporting food security and the economic stability of a nation. Effective land management is a cornerstone of plantation success, influencing productivity, sustainability, and production efficiency. Proper land management can boost yields, while poor management can lead to decreased quality and quantity of produce. Thus, selecting, maintaining, and developing land with care is essential (Hartati & Sitanggang, 2010), to ensure a sustainable future for the plantation sector.

Research indicates that climate change—manifesting in rising temperatures, irregular rainfall, and shifting weather patterns—directly impacts plant growth and yield (Kim & Lee, 2023; Sánchez-Bermúdez et al., 2022; Ullah et al., 2021). Each type of land provides unique conditions that influence crop development, making land suitability a vital factor for sustainable and productive agriculture (Sahputra et al., 2023). Choosing the right land for specific crops not only helps farmers and companies optimize yields but also supports ecosystem balance (Bhareti & Panwar, 2012; Metkono et al., 2023; Swain et al., 2024). Achieving the best results requires a comprehensive understanding of soil properties, climate, and local ecology (Ramadan & Firmansyah, 2023).

Despite the wealth of research on land suitability and management methods, a significant gap remains in integrating advanced decision-making tools to address the complexities of modern plantation agriculture. Existing studies often focus on individual methods, such as Profile Matching or AHP, without exploring their combined potential to deliver more precise and actionable insights. Furthermore, many current approaches lack scalability and adaptability to diverse agricultural contexts, limiting their practical application for farmers and policymakers. This gap highlights the need for innovative solutions that combine robust decision-making techniques with practical implementation strategies.

Given the importance of aligning plantation crops with suitable land, a decision support system (DSS) is essential. Such a system can optimize agricultural production by providing land recommendations based on crop types (Mangape et al., 2021; Negarawan et al., 2022; Vol et al., 2021). Consequently, this study explores the development of a DSS to assess land suitability for plantation crops using the Profile Matching and Analytic Hierarchy Process (AHP) methods..

## 2. Previous Findings

Previous studies have developed various Decision Support Systems (DSS) to help analyze plant suitability for land. For example, (Simbolon & Sihotang, 2020) developed a DSS to determine land suitability for andaliman plants in Merdeka District, Karo Regency, using the Profile Matching method. This system considers criteria such as soil classification, land conditions, and climate, with the results of the study showing that Jaranguda Village is the most suitable location for andaliman cultivation.

In addition, (Wolo et al., 2023) developed a Profile Matching interpolation method for a decision support system that helps determine the types of horticultural plants that are suitable for land conditions in Napugera Village. This method assesses eight criteria, including temperature, rainfall, air humidity, soil type, soil texture, soil pH, land slope, and topography. The results showed that shallots with a final value of 3.764 were suitable for cultivation in the area.

On the other hand, the AHP method has been applied in land suitability analysis for various purposes. For example, research by (Hussain et al., 2024) integrated AHP and Multi-Criteria Decision Analysis (MCDA) techniques to assess and prioritize agricultural land suitability in Southern Punjab, Pakistan. This approach helps in making more informed decisions regarding agricultural land use.

In addition, (Malczewski, 2004) conducted a critical review of the use of GIS-based AHP as a multi-criteria analysis technique for land suitability analysis. This study highlights the advantages and limitations of the method in the context of land use planning.

By integrating Profile Matching and AHP, this study aims to bridge the identified gap and provide appropriate recommendations for the most suitable plantation land based on a set of criteria used. The AHP method is used to determine the weight of the criteria based on the decision maker's preferences, while Profile Matching is used to compare land profiles with the specific needs of a particular crop. The implications of this study offer a practical tool for farmers or agricultural companies to make informed decisions, optimize crop yields, and support sustainable agriculture.

## 3. Research Methodology

This research consists of several stages, including: data collection, DSS modeling, application development, and evaluation. Figure 1 shows the sequence of these processes.

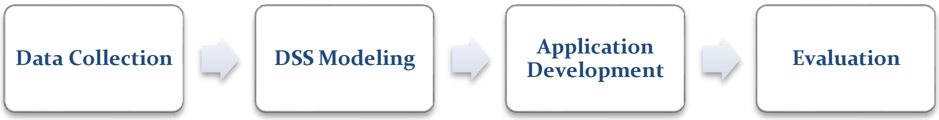


Figure 1. Research Stages

### 3.1 Data Collection

At this stage, two types of data are used: primary and secondary sources. The primary data comes from interviews with experts, including Mr. Safrijal, S.P., M.Si, an agriculture expert at Malikussaleh University. The secondary data is sourced from the 2011 technical guidelines on land evaluation for agricultural commodities published by Indonesia's Agricultural Research and Development Agency under the Ministry of Agriculture. Additionally, the author gathers supplementary information through relevant books, online resources, and academic journals related to the research topic.

## 3.2 DSS Modelling

This study integrates the Profile Matching model with the Analytical Hierarchy Process (AHP) to enhance decision-making. The model developed comprises several stages, which include:

1. Determining Criteria and Alternatives
   The study utilizes eight distinct criteria, as detailed in Table 1. These criteria form the foundation for evaluating the alternatives. The alternatives to be assessed are outlined in Table 2. Each alternative is evaluated based on the criteria presented in Table 1 to facilitate a structured decision-making process.

Table 1. Criteria

| Criteria | Name of Kriteria |
|---|---|
| C1 | Temperature |
| C2 | Water Availability |
| C3 | Oxygen Availability |
| C4 | Rooting Media |
| C5 | Nutrient Retention |
| C6 | Erosion Hazard |
| C7 | Flood Hazard |
| C8 | Land Preparation |

Table 2. Alternative

| Alternative | Name of Alternative |
|---|---|
| A1 | Rubber |
| A2 | Coconut |
| A3 | Palm Oil |
| A4 | Coffee |
| A5 | Cocoa |
| A6 | Cloves |
| A7 | Tea |
| A8 | Tobacco |
| A9 | Sugarcane |
| A10 | Cotton |
| A11 | Kapok |
| A12 | Melinjo |

2. Determining Weights for Each Criterion
   The weights for each criterion, as shown in Table 1, were determined using the Analytical Hierarchy Process (AHP) method. This approach involved a pairwise comparison of the criteria's importance, conducted by an expert from the Faculty of Agriculture at Malikussaleh University, Mr. Safrijal, S.P., M.Si. The consistency of the resulting comparisons was then evaluated by calculating the consistency matrix using the following equation:

$$CI = \frac{\lambda maks - n}{n - 1} \quad \text{(1)}$$

$$CR = \frac{CI}{IR} \quad \text{.......... (2)}$$

3. Evaluation of Alternatives Based on Criteria
   The evaluation of each alternative is conducted based on the values of each land parameter, as outlined in Table 1. These values are then classified into suitability levels by assigning scores as follows: 4 (Highly Suitable, S1), 3 (Moderately Suitable, S2), 2 (Marginally Suitable, S3), and 1 (Not Suitable, N) (Djaenudin et al., 2011). This classification method follows the guidelines provided in the book *Technical Instructions for Land Evaluation for Agricultural Commodities* published by the Center for Soil Resource Research and Development, Agricultural Research and Development Agency, Ministry of Agriculture.
4. Developing a Profile for Each Alternative
   The profile for each alternative represents the ideal conditions for various types of plantation crops. These profiles are based on the technical guidelines for land evaluation tailored to specific agricultural commodities.
5. Profile Matching
   The ideal profile of each alternative is compared against the land profile. This comparison is conducted by calculating the distance between the two profiles using the following equation:

   $$GAP = PROPILE\ TARGET - PROFILE\ VALUE \quad \text{.......... (3)}$$

6. Calculation of Suitability Value
   Once the competency gap has been calculated, the next step involves assigning weights to the gap values. This process helps quantify the importance of each criterion, providing a clearer perspective on how closely the expected profile aligns with the actual profile of the alternative being assessed. The weights are assigned based on predefined values (Budi Setiawan, Maksudi, 2021). After the gap value weighting is completed, the subsequent step is to calculate the core factors (primary criteria) and secondary factors (supporting criteria), as outlined by (Mahendra, G. S., Tampubolon, 2023), using the equation provided below.

   $$NCF = \frac{\sum NC(i,s,p)}{\sum IC} \quad \text{.......... (4)}$$

   $$NFS = \frac{\sum NS(i,s,p)}{\sum IS} \quad \text{.......... (5)}$$

   Finally, the total suitability value is determined by applying the following equation:

   $$Total = (x)\%NCF + (x)\%NFS \quad \text{.......... (6)}$$

7. Selecting the Optimal Alternative
   Based on the calculated results, the alternative with the highest score should be chosen as the optimal solution. This alternative is deemed to most effectively fulfill the established criteria and align with the desired objectives.

## 3.3 Application Development

The development of this application involves implementing the chosen method into software, which will be built using the PHP programming language and MySQL database. The system's process begins when the user logs in and is directed to the dashboard page. Here, the user inputs the criteria and alternatives along with the values obtained from actual land conditions. The system then calculates the AHP values, followed by the profile matching process, to generate ranked recommendations for suitable crops based on the land conditions.

## 3.4 Evaluation

Once the decision support system application is complete, the next step is to evaluate its performance. The first evaluation involves application testing, which uses black-box testing to verify the functionality of the developed system. Following this, the method testing stage is conducted by comparing the accuracy of manual calculations with those produced by the application.

# 4. Results and Findings Analysis

## 4.1 Profile Matching – AHP Analisys

The analysis of land suitability using the Profile Matching and AHP (Analytic Hierarchy Process) model involves several stages as follows:

1. The initial stage involves determining the importance comparison values between criteria based on expert input. This is followed by the pairwise comparison matrix process to produce the desired priority weights, as shown in Table 2.

Table 2. Results of Normalization of Comparison Matrix

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | PV | Bobot |
|---|---|---|---|---|---|---|---|---|---|---|
| **C1** | 0,28 | 0,59 | 0,39 | 0,19 | 0,24 | 0,20 | 0,10 | 0,18 | 2,17 | 0,27 |
| **C2** | 0,06 | 0,12 | 0,26 | 0,28 | 0,16 | 0,13 | 0,26 | 0,12 | 1,38 | 0,17 |
| **C3** | 0,09 | 0,06 | 0,13 | 0,28 | 0,16 | 0,20 | 0,26 | 0,18 | 1,36 | 0,17 |
| **C4** | 0,14 | 0,04 | 0,04 | 0,09 | 0,24 | 0,20 | 0,10 | 0,12 | 0,98 | 0,12 |
| **C5** | 0,09 | 0,06 | 0,06 | 0,03 | 0,08 | 0,13 | 0,10 | 0,12 | 0,68 | 0,09 |
| **C6** | 0,09 | 0,06 | 0,04 | 0,03 | 0,04 | 0,07 | 0,10 | 0,12 | 0,55 | 0,07 |
| **C7** | 0,14 | 0,02 | 0,03 | 0,05 | 0,04 | 0,03 | 0,05 | 0,12 | 0,48 | 0,06 |
| **C8** | 0,09 | 0,06 | 0,04 | 0,05 | 0,04 | 0,03 | 0,03 | 0,06 | 0,40 | 0,05 |
| **Total** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |

From this stage, weights for each criterion are obtained as follows: C1 = 0.26, C2 = 0.23, C3 = 0.14, C4 = 0.12, C5 = 0.08, C6 = 0.07, C7 = 0.06, and C8 = 0.04. The CI value is 0.164, RI is 1.48, and CR (Consistency Ratio) equals CI/RI, resulting in 0.111. It is noted that since CR <= 0.1, the consistency ratio in this case is acceptable. The obtained weights are then used in the profile matching stage.

2. The profile matching calculation begins with calculating the competency gap by matching the attribute values with target values. In this context, the real condition represents attribute values, and plant requirements serve as target values. Competency gap calculation is performed using Equation 3.
3. Next, the core factors and secondary factors are calculated using Equations 4 and 5, respectively.

Table 3. Calculation of CF and SF

| Alternatif | NCF | NSF |
|---|---|---|
| A1 | 2,70 | 2,83 |
| A2 | 2,90 | 2,83 |
| A3 | 3,40 | 2,83 |
| A4 | 2,70 | 2,83 |
| A5 | 3,10 | 2,83 |
| A6 | 3,80 | 2,83 |
| A7 | 2,70 | 2,83 |
| A8 | 2,70 | 2,50 |
| A9 | 2,90 | 2,50 |
| A10 | 2,90 | 2,83 |
| A11 | 3,00 | 2,83 |
| A12 | 2,70 | 2,83 |

4. After obtaining parameter weights and performing the profile matching calculation, the ranking stage is conducted using Equation 6. The land classification results obtained using five land conditions are presented in Table 4.

Table 4: Land Suitability Classification

| No | Land | Classification Results |
|---|---|---|
| 1 | Buket Rata, North Aceh | The top three crops with the highest land suitability are cloves with a preference score of 3.821, palm oil, and tea, both with a score of 3.596. |
| 2 | Reulet, North Aceh | The top two crops with the highest suitability are cocoa with a preference score of 3.22, and coconut with a score of 3.16. |
| 3 | Geulanggang Kulam, Bireuen | The top three crops with the highest land suitability are cloves with a score of 3.41, palm oil with a score of 3.35, and cocoa with a score of 3.99. |
| 4 | Sawang, North Aceh | The top three crops with the highest land suitability are cloves with a score of 3.41, palm oil with a score of 3.17, and cocoa with a score of 2.99. |
| 5 | Coastal Land, Krueng Geukuh, North Aceh | The top two crops with the highest land suitability are sugarcane with a score of 3.353, and cloves with a score of 3.173. |

### 4.2 Application Development

In this study, the design of a decision-making model is implemented by building a simple application to assist decision-makers in determining the most suitable land for certain plantation crops. This application includes key features such as data manipulation for criteria and alternatives, setting criteria weights, and land suitability analysis using the Profile Matching and AHP methods. Here are some displays of main process in the application:

1. Input Paired Comparison Values

   In this section, users input comparison values for each criterion related to plantation land suitability. These values are based on expert assessments, reflecting the importance of each criterion.

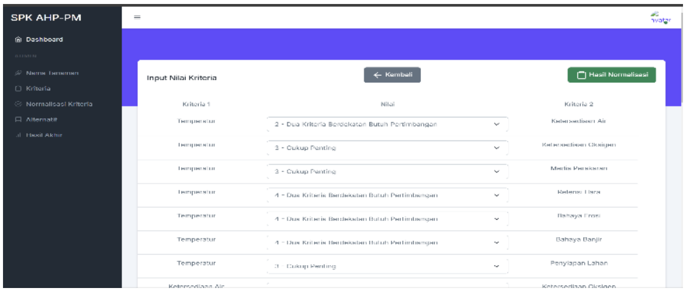


Figure 2. Input of Paired Comparison Values

   Once the comparison values are entered, the system normalizes them to obtain the necessary parameter weights, as illustrated in Figure 3.

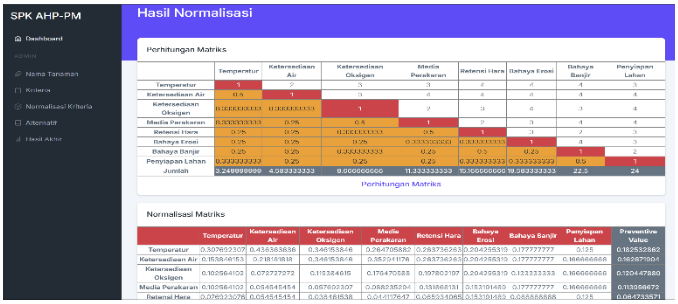


Figure 3. Normalization Results

2. Input Alternative Values

   Here, users input alternative values based on actual land conditions observed in the field. This process involves comparing real land conditions with those specified in the 2011 agricultural land evaluation guide. Figure 4 shows the process of entering these alternative values.

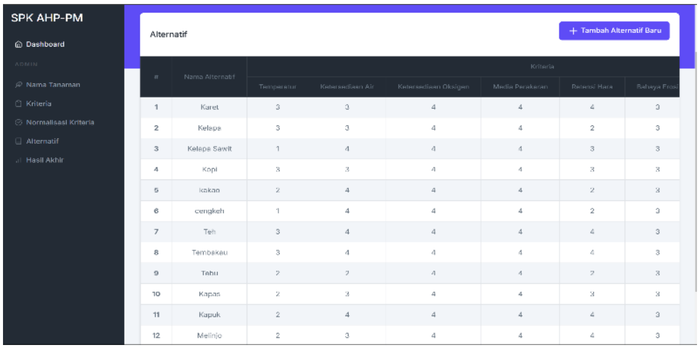

Figure 4. Input of Alternative Values

After inputting values for each alternative, the system proceeds with calculations, starting with the core factor and secondary factor, and finally ranks the options based on these calculations, as shown in Figure 5.

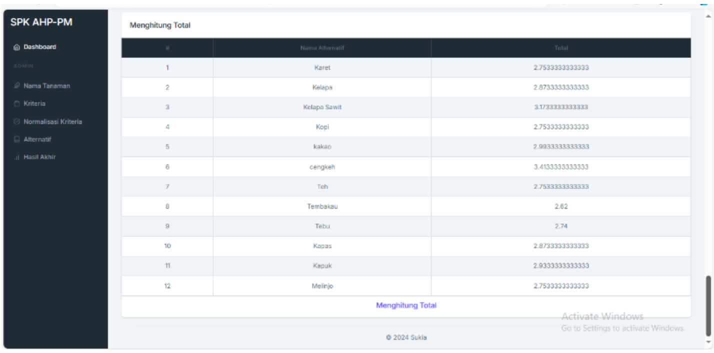

Figure 5. Ranking Results

This system simplifies the decision-making process by presenting the analysis results in an easy-to-use format so that users can quickly understand land suitability for various crops. With these features, this application supports users in making the right decisions to optimize land use for sustainable plantation management. Here are some displays of the process in the application.

## 4.3 Evaluation

In this study, the testing process is divided into two stages: application testing and method testing. Application testing focuses on evaluating the system's functionality and performance in completing assigned tasks, while method testing assesses the accuracy of the program's calculations compared to manual calculations.

1. Application Testing

   Application testing uses a black-box approach, allowing users to evaluate the system's functionality by observing its responses to various input scenarios, as presented in Table 5.

Table 5. Testing result

| No | Testing | Test Case | Expected Results | Test Results | Conclusion |
|---|---|---|---|---|---|
| 1 | Login Form | Click Sign in Button | Displaying Home Page | As Expected | Valid |
| 2 | Register Form | Click Register Button | Displaying Register Page | As Expected | Valid |
| 3 | Alternative Page | Click on Alternative Menu | Displaying Alternative Page | As Expected | Valid |
| 4 | Add Alternative | Click Add Data Button | Displaying Alternative Add Data Form | As Expected | Valid |
| 5 | Edit Alternative | Click Edit Alternative Button | Displaying Alternative Edit Form | As Expected | Valid |
| 6 | Delete Alternative | Click Delete Alternative Button | Displaying Alternative Delete Form | As Expected | Valid |
| 7 | Criteria Page | Click on Criteria Menu | Displaying Criteria Page | As Expected | Valid |
| 8 | Add Criteria | Click Add Criteria Button | Displaying Add Criteria Form | As Expected | Valid |
| 9 | Edit Criteria | Click Edit Criteria Button | Displaying Edit Criteria Form | As Expected | Valid |
| 10 | Delete Criteria | Click Delete Criteria Button | Displaying Delete Criteria Form | As Expected | Valid |
| 11 | Normalization Criteria Page | Click on Normalization Criteria Menu | Displaying Normalization Criteria Page | As Expected | Valid |
| 12. | Add Criteria Comparison Value | Click Add Button | Displaying Comparison Value Input Page | As Expected | Valid |
| 13 | Add Alternative Value | Click Add Data | Displaying Alternative Add Value Form | As Expected | Valid |
| 14 | Edit Alternative Value | Click Edit Button | Displaying Alternative Edit Form | As Expected | Valid |
| 15 | Result of Profile Matching- AHP Method | Click Calculation Result Menu | Displaying Plantation Land Suitability Calculation Results | As Expected | Valid |
| 16 | Logout Form | Click Exit Menu | Displaying Logout Form | As Expected | Valid |

2. Model Testing

Model testing aims to ensure that the program's calculations align accurately with manual calculations. In this study, the program's results were consistent with manual calculations. Additionally, experts reviewed the land conditions and system recommendations, confirming that the system's outputs were reliable and aligned with expectations. The system was approved due to its accuracy and consistency with expert assessments.

## 5. Conclusion

This research successfully developed a decision support system using PHP and MySQL, implementing the Profile Matching and AHP methods to assess the suitability of plantation land. The study demonstrates that the Profile Matching - AHP approach can effectively guide decision-making by identifying key issues, establishing criteria for evaluation, assigning appropriate weights, and performing calculations to generate a ranked list of options. Key criteria used in this analysis include Temperature, Water Availability, Oxygen Availability, Rooting Media, Nutrient Retention, Erosion Hazard, Flood Hazard, and Land Preparation. The alternatives assessed in this study were different types of plantation crops.

The final results from analyzing all land conditions are as follows: the Buket Rata land is most suitable for Clove with a preference score of 3.821, followed by Oil Palm and Tea at 3.596. Reulet land is best suited for Cocoa (3.22) and Coconut (3.16). Geulanggang Kulam land is optimal for Clove (3.41), Cocoa (3.35), and Oil Palm (3.29). Sawang land ranks highest for Clove (3.41), followed by Oil Palm (3.17) and Cocoa (2.99). Lastly, Pesisir Laut land favors Sugarcane (3.353) and Clove (3.173).

## 6. Acknowledgements

We extend our gratitude to the team members for their dedication and hard work throughout this research. Special appreciation goes to Mr. Safrijal, S.P., M.Si, an agricultural expert at Malikussaleh University, whose invaluable support and expertise were instrumental in completing this study.

## 7. Author's Note

There are no conflicts of interest regarding the publication of this article. Data and papers are free from plagiarism.

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