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Decision Support System for Determining the Right Fertilizer for Coffee Plants Using the AHP Method

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Abstract—Coffee is one of the leading commodities in the plantation subsector in Indonesia. Padangan Hamlet is a hamlet located in Kandangan District, Temanggung Regency, with the majority of the community as coffee farmers. However, over time, coffee productivity has decreased and a strategy is needed to increase coffee productivity. To improve the quality of good coffee, special knowledge is needed regarding fertilization of coffee plants. Determining the right fertilizer for coffee farmers is an important problem because it can affect the crop yield. In providing solutions related to this problem, this study developed a decision support system for determining the right fertilizer for coffee plants using the AHP method. The system was developed using the waterfall process model with PHP and MySQL programming languages based on the Codeigniter framework. The system was tested for functionality and validity. In addition, the system was also evaluated and a feasibility study was carried out on the system against 8 respondents consisting of members of the farmer group. The results showed that the percentage value was 81.852% which indicated that the system was categorized as very feasible.
Keyword *: Analytical Hierarchy Process, Codeigniter, Coffee, Decision Support System, Temanggung*

I. INTRODUCTION

Coffee is one of the leading commodities in the plantation sub-sector in Indonesia [1]. This is because coffee has good market opportunities both domestically and abroad. Most of the coffee production in Indonesia is a plantation commodity that is sold to the world market. [2]. According to the International Coffee Organization (ICO), coffee consumption increases from year to year, so that increasing coffee production in Indonesia has a great opportunity to export coffee to major coffee consuming countries in the world such as the European Union, the United States and Japan. Temanggung Regency as one of the centers of coffee producing areas, with the highest production level number one in Central Java [3]. In 2022, coffee production in Temanggung reached 11,126 tons.

Padangan Hamlet is a hamlet located in Kandangan District, Temanggung Regency, with a mountainous geography and the majority of the community works as coffee farmers. However, over time, coffee productivity in Padangan Hamlet has decreased and a strategy is needed to increase coffee productivity. To improve the quality of good coffee, special knowledge is needed regarding fertilization of coffee plants. [4]. Plant fertilization aims to add nutrients that are not present or available in the soil that plants need for vegetative and reproductive growth in order to obtain quality fruit mass.[5]. Determining the right fertilizer for coffee farmers in Temanggung is an important problem because it can affect the crop yield. The problem experienced is that the selection of fertilizers in the Temanggung area is still less effective. Because in the selection of fertilizers, farmers get data from the Temanggung Agriculture Service to get recommendations for the best types of fertilizers with valid data. Therefore, all factors that influence sustainable agricultural development, both supporting factors and limiting factors, must be considered from the start, starting from determining the best fertilizer for coffee plants which is poured into an application that can be one of the strategic solutions to increase coffee production in Padangan Hamlet.

Previous research related to this research with the title of developing a fertilizer type recommendation system for oil palm plants using the AHP (analytical hierarchy process) method, by: As-Siddiqi, M., H., et al. 2022. The purpose of this study is to create a recommendation system using the analytical hierarchy process (AHP) algorithm method. The variables used are 3 criteria (soil type, plant age and water content) with 3 fertilizer alternatives (urea, KCL and ZA). The results of this study are a web-based palm oil fertilizer recommendation system with Black Box testing. In the results of testing the manual AHP calculation method in Microsoft Excel with AHP Calculation in the System, the average value obtained from the calculation is below 1, which means that the consistency value of the calculation can be used with organic fertilizer as the best fertilizer choice. However, in this study there is no calculation report section that can display the results of the best fertilizer in the form of a report [6].

Research on the selection of effective fertilizers for shallot cultivation in Demak Regency, by Mahendra, A., & Saefurrohman, S., 2022. The purpose of this study was to create a decision support system in fertilizer application by combining

the analytical Hierarchy Process (AHP) method and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The advantage of this study is that it uses a hybrid method between AHP and TOPSIS. However, in variable processing, TOPSIS is only used in the ranking system from the results of the AHP calculation process. The variables in this study use 5 variables (Soil Type, Age, Temperature and Soil Ph) with 5 alternatives (Npk MuBara, Kcl, Urea, Sp-36 and ZA) The results of this study are recommendations for effective fertilizers for shallot cultivation in Demak Regency, namely Npk Mutiara 16:16:16 fertilizer and ZA fertilizer [7].

Decision support system for determining the best coffee land using the AHP (analytical hierarchy process) method by Rahmatullah, S., & Abdurahman, R., 2020. The purpose of this study is to facilitate the people of Gunung Kidul Village in determining the best coffee land so that they can increase the amount of coffee production. The results of this study are the determination of the best coffee land with several variables used, namely organic elements, soil minerals, water sources, land slopes, and previous plants. The disadvantage of this study is that it still uses the Borland Delphi 7 programming language with the Microsoft Access database. This still causes difficulties in reporting and analyzing continuous data [8].

From the problems above, this study will design a fertilizer recommendation system so that farmers can find out the right type of fertilizer for web coffee plants with the Analytical Hierarchy Process (AHP) method in providing fertilizer recommendations for coffee plants. So that with this application it is expected to help coconut coffee farmers in choosing the type of fertilizer that will be used later.

II. RESEARCH METHODS

The research methods used in this stage are as follows:

1. Data Collection Method
   This method is used in the process of collecting data using various sources. In the process of collecting data using the following methods:
   a. Interview
      At this stage, the researcher conducted a direct interview with the leader of the Padangan Hamlet farmer group who was directly related to the case study being conducted in the research.
   b. Observation
      Direct observation of the research object in order to obtain systematic data on the matters being studied.
   c. Literature Study
      Direct observation of the research object in order to obtain systematic data on the matters being studied.

2. System Development Methods
   a. Data Analysis
   b. System Design
   c. System Design
   d. System Implementation
   e. System Testing

3. Research Flow
   This research flow is carried out following the following stages:
   a. Literature study sourced from research results such as journals, proceedings, literature studies aim to analysis problems, formulate backgrounds, state of the art and theoretical basis.
   b. Data Collection Analysis: Collection and Analysis of Agricultural Data, Plants, Fertilizers and Important Variables
   c. System Design: At this stage, what will be designed includes: Use Case Diagram, Hierarchy Input Process Output (HIPO) and Class Diagram.
   d. System Design: At this stage, what will be designed includes input design, output design, technology design and database design.
   e. System Implementation: At this stage, the creation of the entire application program begins with the PHP programming language and MySQL Database
   f. System Testing: At this stage, the System Testing utilizes the Blackbox and Validity methods.
   g. System Evaluation and Feasibility Study: Measuring the Effectiveness of System Feasibility.
   h. Mandatory Reporting and Output: Preparing research reports and publications

   To further clarify the flow of this research, it can be seen in Figure 1.

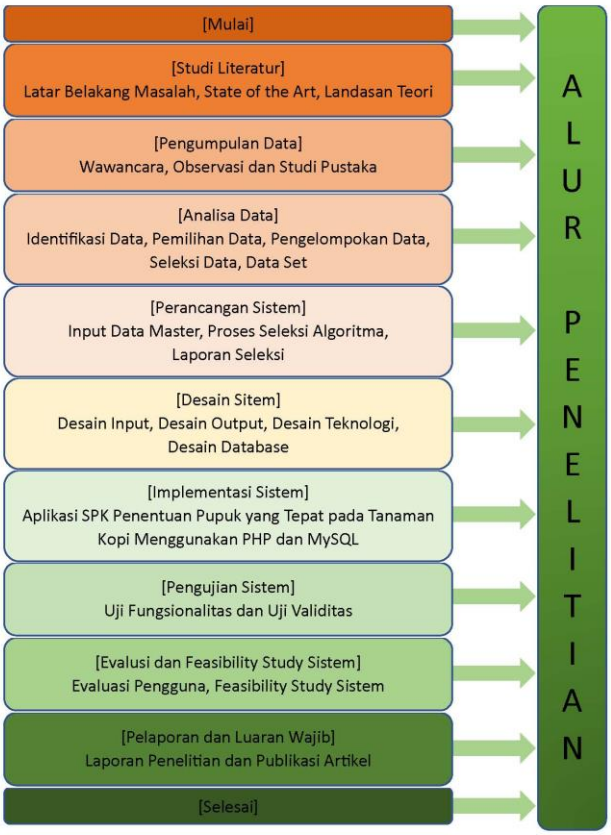

Figure 1. Research Flow

III. RESULT AND ANALYSIS

The results and analysis in this study discuss the data analysis process, implementation of the AHP algorithm, system testing and evaluation and feasibility study of the system in determining the right fertilizer for coffee plants.

3.1 Data Analysis

In the process of Data Analysis, data identification, data selection, data grouping, data selection and data sets are carried out[9]. So that alternatives and criteria are obtained as an important part in the implementation of the required system. Criteria data is used as a reference/basis for the assessment. In the criteria, the criteria code and criteria name can be adjusted according to the needs of the system. The criteria data is presented in table 1.

Table 1. Criteria Data

No	Code	Criteria Name
1	K1	Plant Age
2	K2	Land Area
3	K3	Soil pH
4	K4	Soil Slope
5	K5	Water Content

In determining the importance and priority level of each criterion, a basic scale of paired comparisons can be used, as presented in Table 2.

Table 2. Basic scale of paired comparisons

No	Intensity of Interest	Information
1	1	Both Elements Are Equally Important
2	3	One element is slightly more important than the other
3	5	One element is more important than the other
4	7	One element is clearly more absolutely important than the other
5	9	One element is absolutely important than the other
6	2, 4, 6, 8	Values between two adjacent considerations
7	Reciprocal	If element one has one of the above values compared to element j, then j has the opposite value when compared to element i

Next, alternative data is something/someone who will be assessed. Alternatives contain alternative codes and alternative names according to the results that are the goal of the system.

Table 3. Alternative Data

No	code	Criteria Name
1	A1	Urea
2	A 2	KCL
3	A 3	ZA
4	A 4	Kieserit

Based on the criteria and alternative data, a problem definition is carried out in achieving the goal. In carrying out the problem definition, it is done by determining the relation or relationship in the criteria and alternatives in achieving the goal. In carrying out the problem definition, it is presented in Figure 2 below.

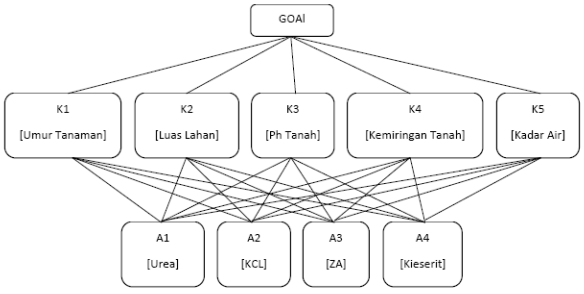

Figure 2. Problem definition

3.2System Design

In the system design stage, it is useful to provide an overview of the process of system implementation. In this stage, a flowchart of the AHP method process is presented in Figure 2, a flowchart of determining the type of fertilizer is presented in Figure 3 and a flowchart of the decision support system for determining fertilizer is presented in Figure 4.

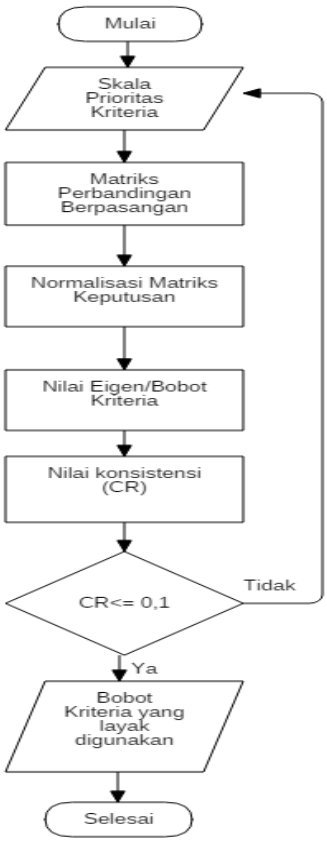

Figure 3. Flowchart of AHP Method

In the first process of the AHP method flowchart, the data input process will be carried out from the priority scale of the criteria. Then a pairwise comparison matrix is made from the existing criteria. After that, the matrix normalization process is carried out. From these results, calculations are then carried out for the criteria weight values, after which the consistency value is calculated. If the consistency value is less than 0.1, the AHP process will be repeated from the beginning, if it is more than 0.1, the criteria weight that is suitable for use is obtained.

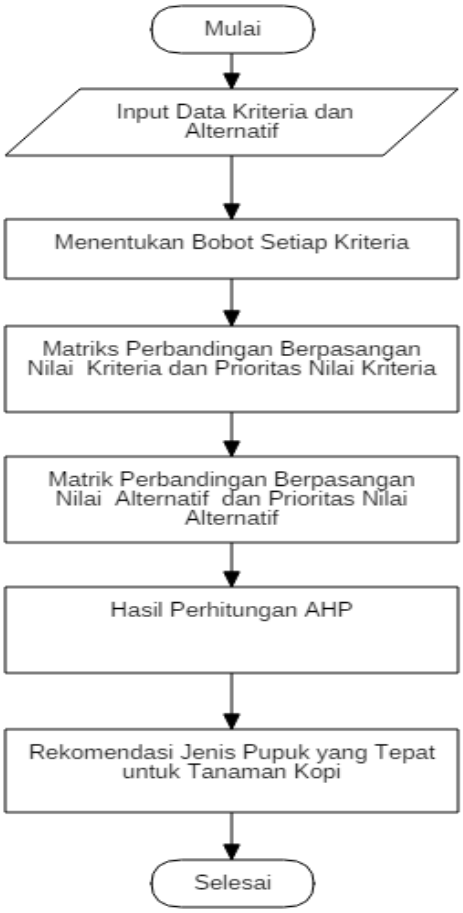

Figure 4. Flowchart for Determining the Right Fertilizer for Coffee Plants

The first thing to do is to add criteria and alternative data and determine the weight of each criterion and alternative that has been added. Then a pairwise comparison matrix is created and the priority value is calculated to check whether the weight value of the criteria can be used. Likewise with alternatives, a pairwise comparison matrix is performed and the priority value is calculated to check whether the weight value of the alternative can be used. Finally, the final calculation is carried out to obtain the results and ranking of the best fertilizer types.

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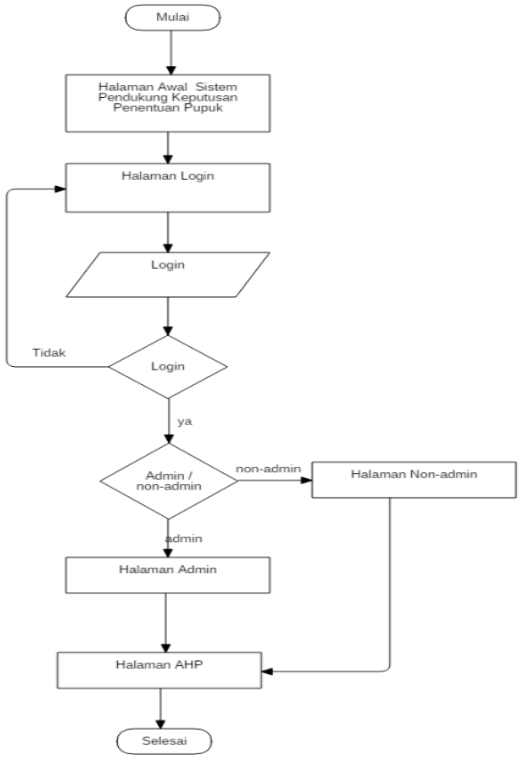

Figure 5. Flowchart of SPK Fertilizer Determination

First, the user is directed to the main page of the website. Then enter the login page and enter the username and password. If it does not match, it will return to the website login page, if correct, the system will check whether the user has admin access or not. If admin, it will enter the admin page, if not, it will enter the non-admin page. Users can select the AHP menu to carry out the AHP process in determining the right fertilizer for coffee plants.

3.3System Design

The developed system carries the concept of OOP (Object-Oriented Programming). OOP itself is a programming method that is oriented towards objects where there are classes and objects that interact with each other so that a program can be created [10]. So that in visual modeling the system uses UML (Unified Modeling Language). UML can be interpreted as a standard language for visualization, design, and documentation of systems, or a standard language for writing blueprints for software [11]. In this study, it will provide a visualization of the system including use case diagrams and class diagrams. Use case diagrams describe the interaction between the system and the actor and can describe the type of interaction between system users and their systems [12]. While the class diagram is a diagram used to display classes in the form of packages to meet one of the needs of the package that will be used later.

The use case diagram of the decision support system for determining the right fertilizer for coffee plants using the AHP method is presented in Figure 5.

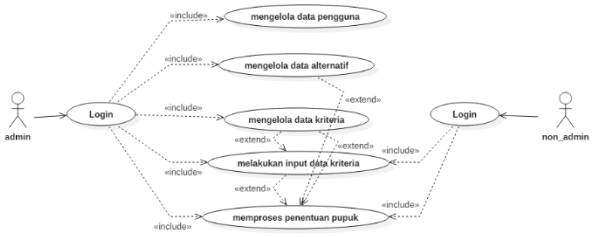

Figure 6 Use Case Diagram of Decision Support System for Fertilizer Determination

In the developed system, there are 2 levels of users, namely users as admins and non-admin users. Where each user has features according to the level they have.

3.4System Implementation

The implementation stage of the system of the decision support system for determining the right fertilizer for coffee plants, this is the most important part in the innovation of system development. The process stages in the implementation of the system are as follows:

1. System Home Page

   The system home page can be seen in the following image the show figure 7.

Figure 7. System home page

Next, to start this system, the user will be asked to log in to the system as shown in the following image.

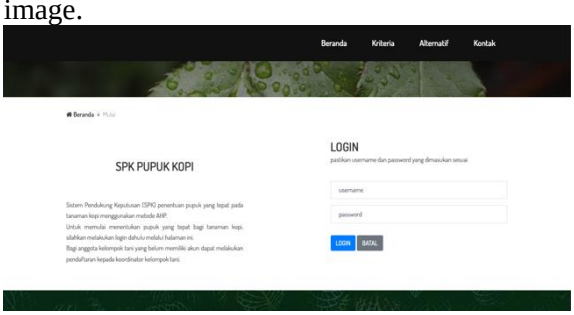

Figure 8. System Login Page

2. Criteria Management Page
   On the criteria management page, users can set the criteria used in determining the right fertilizer for coffee plants. The page is presented in the following figure.

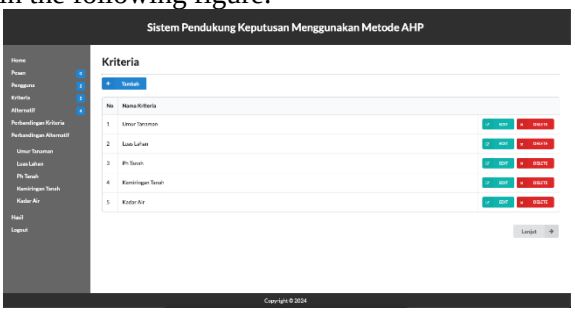

Figure 9. Criteria Management Page

3. Alternative Management Page
   The alternative management page is intended for users to determine alternative destinations. The page is presented in the following image.

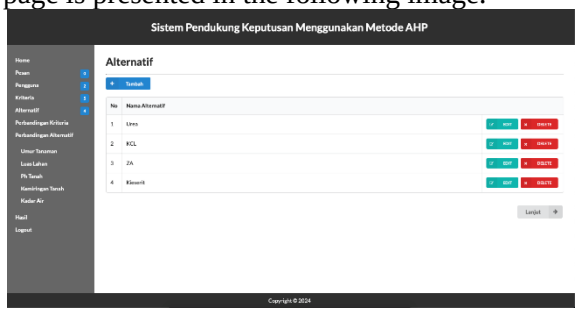

Figure 10. Alternative Management Page

4. Criteria Comparison Form Page
   The criteria comparison page is used to determine the weight of each criterion based on the level of importance according to needs. The results of the comparison process will then be presented in the following figure.

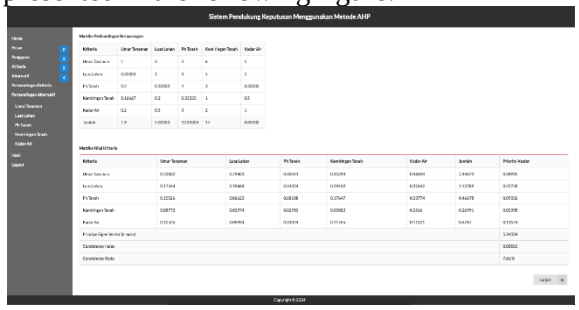

Figure 11. Pairwise Comparison Criteria Page

5. Alternative Comparison Form Page
   On the alternative form page, users can determine the importance weight value of each alternative against the criteria based on needs. The results of the alternative comparison process against the plant age criteria are presented in the following figure.

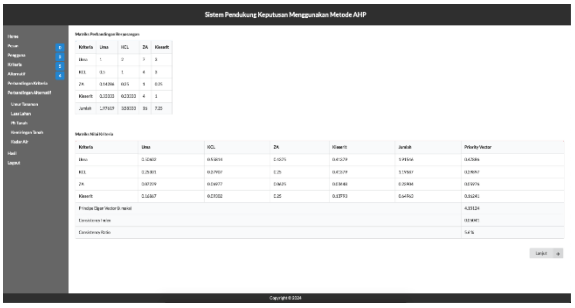

Figure 12. Alternative Comparison Page for Plant Age

The results of the alternative comparison process for land area criteria are presented in the following figure.

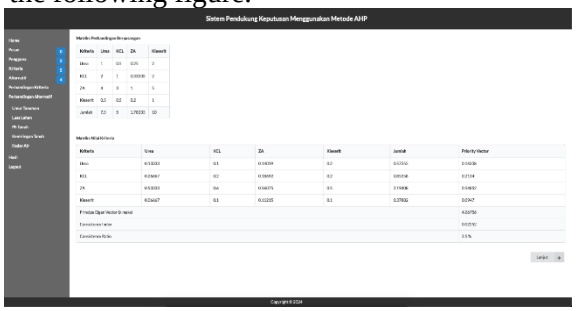

Figure 13. Alternative Comparison Page for Land Area

The results of the alternative comparison process for Soil Ph criteria are presented in the following figure.

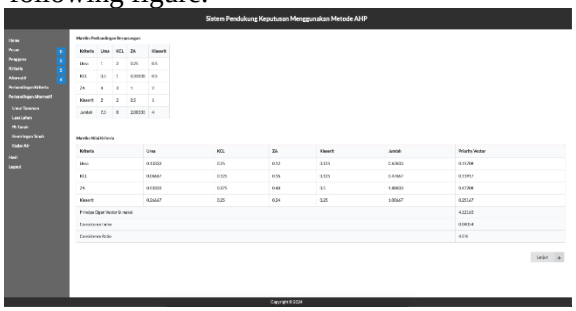

Figure 14. Alternative Comparison Page for Soil Ph

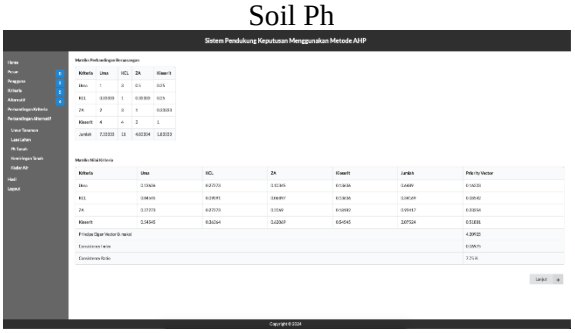

Figure 15. Alternative Comparison Page for Land Slope

The results of the alternative comparison process for water content criteria are presented in the following figure.

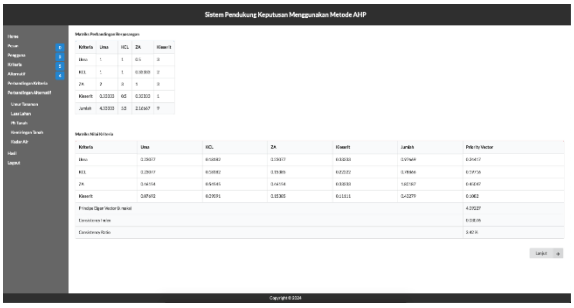

Figure 16. Page Comparison of Alternatives to Water Content

6. Recommendation Results Page
The system recommendation page shows the results of the appropriate fertilizer recommendation process for coffee plants. The recommendation results page is shown in the following image.

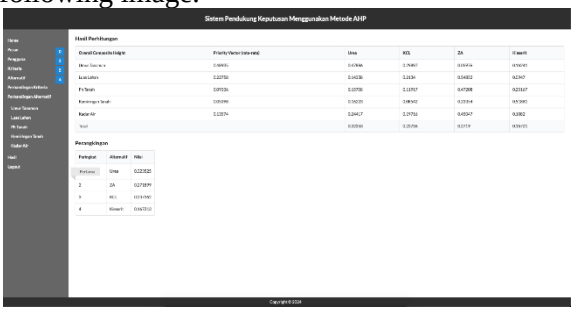

Figure 17. System recommendation results page

3.5 System Testing

The System Testing Process is carried out in two stages of testing, namely Functional Testing and Validity Testing.

1. Functionality Testing

Functionality Testing is a test on the features owned by an application system [13]. This aims to determine whether the features or services in the application have run properly [14]. Testing is carried out on all available system features including true and false test scenarios. Based on the results of the functionality testing that has been carried out, it shows that the application has run well because all test scenarios obtained acceptable results, so the system is declared normal.

2. Validity Testing

Validity Testing is a system testing process by comparing the results of manual algorithm calculations with the results of the application system [15]. The following are the stages in the validity test of the system being developed.

a. Comparative Value

1) Calculation of priority weight of criteria
In calculating the priority weight of criteria, the criteria are arranged in a pairwise comparison matrix to produce the following comparison matrix of criteria.

Table 5 Comparison Matrix of Criteria

#	K1	K2	K3	K4	K5
K1	1	3	5	6	5
K2	0,3333	1	3	5	2
K3	0,2	0,3333	1	3	0,3333
K4	0,1667	0,2	0,3333	1	0,5
K5	0,2	0,5	3	2	1
∑	1,9	5,0333	12,3333	17	8,8333

Based on the table above, the normalization matrix and priority vector criteria can be calculated as follows.

Table 6 Normalization Matrix and Priority Vector

#	K1	K2	K3	K4	K5	Amount	average
K1	0,52632	0,59603	0,40541	0,35294	0,56604	2,44673	0,48935
K2	0,17544	0,19868	0,24324	0,29412	0,22642	1,13789	0,22758
K3	0,10526	0,06623	0,08108	0,17647	0,03774	0,46678	0,09336
K4	0,08772	0,03974	0,02703	0,05882	0,05660	0,26991	0,05398
K5	0,10526	0,09934	0,24324	0,11765	0,11321	0,67870	0,13574

The average value (Priority Vector) is the sum of the eigenvalues divided by the number of criteria. The average value describes the level of importance of the criteria, the higher the value, the higher the level of importance. Next, determine the maximum eigenvalue (lamda) as follows:

$$\lambda_{maks} = \frac{\sum \lambda}{n} \quad (1)$$

$\lambda_{maks} = 5{,}34334$

Calculating the consistency index (CI) value using the formula $CI = \frac{(\lambda_{maks-n})}{(n-1)}$ so that the value is obtained CI = (5,34334-5) / (5-1) = 0,08583. Calculate the consistency ratio (CR) value using the formula CR = CI/IR to obtain the value CR = 0,08583/1,12 = 0,07664. If CR < 0.1, then the pairwise comparison value in the given criteria matrix is consistent. If CR ≥ 0.1, then the pairwise comparison value in the given criteria matrix is inconsistent. So, if it is inconsistent, then the filling of the values in the pairwise matrix in the criteria elements must be repeated. So that the comparison given for the criteria is consistent.

2) Calculation of alternative priority weights
To find the priority weight of the criteria on the alternatives, it is done as many times as the number of criteria. The steps taken are the same as in finding the average (value weight) of the priority in the previous step. The following are the results of the calculation.

a) Comparison of alternatives to plant age
The results of the comparison of alternatives to plant age are presented in the following table.

Table 7. Comparison of alternatives to plant age

K1	A1	A2	A3	A4	amount	average
A1	0,50602	0,55814	0,43750	0,41379	1,91546	0,47886
A2	0,25301	0,27907	0,25000	0,41379	1,19587	0,29897
A3	0,07229	0,06977	0,06250	0,03448	0,23904	0,05976
A4	0,16867	0,09302	0,25000	0,13793	0,64963	0,16241
λ_{maks}						4,15124
CI						0,05041
CR						0,05602

b) Comparison of alternatives to land area
The results of the comparison of alternatives to land area are presented in the following table.

Table 8. Comparison of alternatives to land area

K2	A1	A2	A3	A4	amount	average
A1	0,13333	0,1	0,14019	0,2	0,57352	0,14338
A2	0,26667	0,2	0,18692	0,2	0,85358	0,21340
A3	0,53333	0,6	0,56075	0,5	2,19408	0,54852
A4	0,06667	0,1	0,11215	0,1	0,37882	0,09470
λ_{maks}						4,06756
CI						0,02252
CR						0,02502

c) Comparison of alternatives to soil pH
The results of the comparison of alternatives to soil pH are presented in the following table.

Table 9. Comparison of alternatives to soil pH

K3	A1	A2	A3	A4	amount	Average
A1	0,13333	0,25	0,12	0,125	0,62833	0,15708
A2	0,06667	0,125	0,16	0,125	0,47667	0,11917
A3	0,53333	0,375	0,48	0,5	1,88833	0,47208
A4	0,26667	0,25	0,24	0,25	1,00667	0,25167
λ_{maks}						4,12163
CI						0,04054
CR						0,04505

d) Comparison of alternatives to land slope
The results of the comparison of alternatives to land slope are presented in the following table.

Table 10. Comparison of alternatives to land slope

K4	A1	A2	A3	A4	amount	average
A1	0,13636	0,27273	0,10345	0,13636	0,64890	0,16223
A2	0,04545	0,09091	0,06897	0,13636	0,34169	0,08542
A3	0,27273	0,27273	0,20690	0,18182	0,93417	0,23354
A4	0,54545	0,36364	0,62069	0,54545	2,07524	0,51881
λ_{maks}						4,20925
CI						0,06975
CR						0,07750

e) Comparison of alternatives to water content
The results of the comparison of alternatives to water content are presented in the following table.

Table 11. Comparison of alternatives to water content

K5	A1	A2	A3	A4	amount	average
A1	0,23077	0,18182	0,23077	0,33333	0,97669	0,24417
A2	0,23077	0,18182	0,15385	0,22222	0,78866	0,19716
A3	0,46154	0,54545	0,46154	0,33333	1,80186	0,45047
A4	0,07692	0,09091	0,15385	0,11111	0,43279	0,10820
λ_{maks}						4,09227
CI						0,03076
CR						0,03417

b. Ranking

The ranking stage is the process of determining the best alternative by multiplying the average value of the calculation of the priority weight of the criteria against the average value of the calculation of the alternative weight.

Table 12. Alternative ranking

#	K1	K2	K3	K4	K5	value	rank
K	0,48935	0,22758	0,09336	0,05398	0,13574		
A1	0,47886	0,14338	0,15708	0,16223	0,24417	0,32353	1
A2	0,29897	0,21340	0,11917	0,08542	0,19716	0,23753	3

	897	340	917	542	716	36	
A3	0,05	0,54	0,47	0,23	0,45	0,271	2
	976	852	208	354	047	90	
A4	0,16	0,09	0,25	0,51	0,10	0,167	4
	241	470	167	881	820	21	

Based on the ranking process above, the highest value obtained is A1 (Urea) with a result value of 0.32353. So that urea fertilizer becomes the best fertilizer recommendation for coffee plants is urea based on the calculation of the AHP method. Furthermore, the results are compared with the results of the developed application. From the results of the comparison carried out, the same results were obtained between the results of the manual comparison and the results of the system comparison shown in Figure 18.

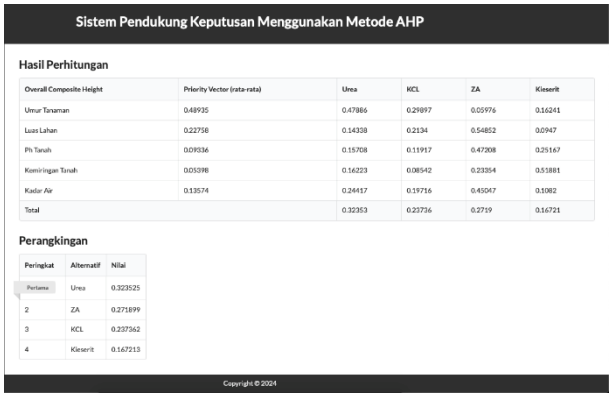

Figure 18. Results of application system calculations

3.6 System Evaluation and Feasibility Study

User evaluation of a system is an effective way to measure various aspects of user performance, satisfaction, and experience [16]. Likert Scale is a commonly used tool to measure attitudes, perceptions, or judgments about various aspects, including the functionality of a web application [17]. Using Likert Scale in functional feasibility studies helps to quantitatively measure the extent to which web application features meet user needs, providing useful insights for further improvement and development[18].Furthermore, functional evaluation of the system is conducted using Likert Scale to measure satisfaction and effectiveness of various aspects of the system. Respondents are asked to rate various features of the system on a scale of 1 to 5, where 1 means "Strongly Disagree" and 5 means "Strongly Agree".

A questionnaire with Likert Scale-based questions was distributed to 9 users of the system. Data were collected and analyzed to calculate the percentage of respondents who gave scores at each level of the Likert Scale. The results were calculated to determine the percentage of feasibility of each feature. The results of the user evaluation are presented in the following table.

Table 13. Results of System Evaluation and Feasibility

No	Question	Results				
		SS	S	N	TS	STS
		5	4	3	2	1
1	The developed application has an easy to understand display.	2	5	2	0	0
2	The language used in the system is easy to understand.	5	3	1	0	0
3	The developed application can be used and understood easily.	2	6	1	0	0
4	The developed application can be used according to its function	2	5	2	0	0
5	The buttons and menus in the developed application work properly.	3	4	2	0	0
6	The developed application can help provide appropriate fertilizer recommendations for coffee plants.	1	6	2	0	0
	Total	15	29	10	0	0
	Score	75	116	30	0	0
	Total Score			221		
	Max Score			270		
	Percentage Value			81.852%		

Furthermore, the Percentage Value (PV) obtained is interpreted according to the eligibility criteria in the following table.

Table 14. Eligibility Categories

Percentage Value (PV)	Criteria
81% < PV ≤ 100%	Very worthy
61% < PV ≤ 80%	Worthy
41% < PV ≤ 60%	Quite worthy
21% < PV ≤40%	Less worthy
0% < PV ≤20%	Not worthy

Based on the table above, the user evaluation in the feasibility study conducted can be said to be very feasible. This is proven by the results of the

feasibility study with a percentage value (PV) of 81.852%. So, the evaluation and feasibility study of the system developed using respondents as many as 8 system users is said to be very feasible.

VI. CONCLUSION

Based on the results of the research and discussion conducted in this study, it can be concluded that:

1. The decision support system for determining the right fertilizer for coffee plants using the AHP method developed using the PHP and MySQL programming languages is able to provide recommendations according to the criteria and alternatives given. In addition, the system was also tested for functionality using black box testing and validity testing of the system results. The test results showed that the functionality and validity tests were said to be good.
2. The system developed was said to be very feasible based on the evaluation and feasibility study of the system was 81.852% with a very feasible category.

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