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Research article

Land Suitability Analysis Using the Modified Profile Matching Method

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ABSTRACT

The plantation sector plays a significant role in Indonesia's economy, particularly in coffee production. In the province of West Nusa Tenggara (NTB), coffee production experienced annual fluctuations from 2018 to 2021. One of the causes is the lack of public understanding in utilizing land according to its natural potential, leading to decreased productivity and land degradation. Based on discussions with plantation experts from Politeknik *LPP* Yogyakarta, this study identifies land characteristics divided into qualitative data, such as drainage and soil texture, and quantitative data, including temperature, rainfall, humidity, elevation, effective soil depth, slope, cation exchange capacity (CEC), base saturation, pH H2O, organic carbon (C-organic) content, and nitrogen (N). The application of the modified profile matching method demonstrates its capability in providing recommendations for coffee crop suitability in East Lombok Regency. Data matching tests between land profile values and coffee crop profile values, involving experts from Politeknik *LPP* Yogyakarta and the NTB Provincial Agriculture Office, resulted in liberica coffee being ranked first in eight sub-districts. However, in one sub-district, Sembalun, robusta coffee did not rank second, as arabica coffee was preferred.

1. Introduction

The growth of Indonesia's agricultural and mining sectors, especially in plantation production, is crucial to the national economy. Data from the Central Bureau of Statistics (*BPS*) reveals that the production of various plantation crops experienced fluctuations between 2018 and 2021. East Lombok Regency in West Nusa Tenggara Province is one of the regions where the growth in plantation crop production has declined [1].

According to *BPS* data, the production of plantation crops in East Lombok Regency from 2018 to 2021 showed varying trends in the yields of coconut (Cocos nucifera L.), coffee (Coffea), and tobacco (Nicotiana tabacum L.). Specifically, coffee production averaged 0.38 thousand tons per year. An interview with a representative from the Provincial Agriculture Office of West Nusa Tenggara indicated that this decline in production can be attributed to various factors, one of which is the community's limited knowledge of appropriate coffee cultivation practices on their land. As a result, land use has been suboptimal, negatively impacting productivity and contributing to soil degradation [2].

According to data from plantation experts at *LPP* Polytechnic Yogyakarta, land characteristics are categorized into qualitative and quantitative data. Qualitative data are assessed using proximity values, while quantitative data are determined through linear interpolation functions within suitability classes. Each crop requires specific characteristics, such as soil pH for Arabica coffee, which falls within the range of ≥5.5 to ≤6.6. In general, land characteristics are interconnected [3]. Experts from *LPP* Polytechnic Yogyakarta highlighted the interdependence of these criteria, such as how temperature influences air humidity—lower temperatures tend to result in higher humidity. To address these complexities, an

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analysis was conducted to provide recommendations on suitable coffee crops for the land in East Lombok Regency.

2. Materials and Methods

2.1. Coffee Plants

Coffee plants are shrubs or small trees belonging to the Rubiaceae family and the Coffea genus. These plants originate from tropical Africa and South Asia. The seeds of several species, such as *Coffea arabica* and *Coffea canephora*, are used to produce coffee beverages.

Coffee is a tree that grows upright with branches that can reach a height of up to 12 meters if left unpruned [4]. Its leaves are oval-shaped with slightly pointed tips, growing in opposite pairs along the stem, branches, and twigs.

Coffee plants have a shallow root system with a taproot that extends to a depth of 45–50 cm. Additionally, numerous lateral roots extend horizontally for 1–2 meters at a depth of approximately 30 cm. Cool and moist soil conditions support the development of these lateral roots [5].

In general, commercially cultivated coffee plants consist of three main species:

1. Coffea arabica: Known as Arabica coffee, it originates from the highlands of Ethiopia and is the first type of coffee to be cultivated.
2. Coffea canephora: Known as Robusta coffee, it was discovered in the Congo in 1898 by Emil Laurent.
3. Coffea liberica: Known as Liberica coffee, it was first found in Liberia and is also grown in various West African countries.

Coffee plants require optimal land conditions to achieve high productivity [6]. Several important factors influence the growth and production of coffee plants, including:

1. Soil Depth: Soil with a depth of more than 100 cm is ideal for coffee root growth, allowing roots to develop well and absorb nutrients optimally.
2. Soil Structure: Loose and fertile soil supports coffee plant growth by providing sufficient space for roots and ensuring the availability of necessary nutrients.
3. Organic Matter Content: A high presence of organic matter in the soil enhances soil fertility and provides a nutrient source for coffee plants.
4. Soil Drainage: Good drainage ensures that water does not stagnate around the roots, preventing root rot and other diseases.
5. Soil pH: Coffee plants grow optimally in soil with a pH between 5.5 and 6.5, which supports nutrient availability and the activity of beneficial soil microorganisms.

2.2. Land Suitability Classification for Coffee Planting

The classification of land suitability for coffee planting aims to determine how well the land characteristics meet the growth requirements of coffee plants, thereby maximizing both the production and quality of coffee beans. This assessment involves analyzing factors such as climate, physical and chemical properties of the soil, and topography.

Land Suitability Classification According to FAO

The land suitability classification for coffee plants is divided into [7]:

1. Highly Suitable (S1): Land that is highly suitable with no significant limitations.
2. Moderately Suitable (S2): Land that is suitable with minor limitations.
3. Marginally Suitable (S3): Land that is suitable with moderate limitations.
4. Not Suitable (N): Land that is not suitable for coffee plants.

Limiting Factors in Land Suitability

Factors influencing land suitability for coffee plants include:

1. Climate: Annual rainfall, monthly rainfall distribution, and air temperature.
2. Physical Soil Properties: Effective depth, texture, drainage, and waterlogging.
3. Chemical Soil Properties: pH, organic matter content, cation exchange capacity (CEC), and nutrient availability.
4. Topography: Elevation and slope gradient.

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2.3 Decision Support System

A Decision Support System (DSS) is an interactive computer system designed to assist the decision-making process by utilizing data and models to solve unstructured problems [8].

The Decision Support System (DSS) is an interactive computer system created to facilitate decision-making processes by employing data and models to address various unstructured issues [9].

2.4. Linear interpolation

Linear interpolation is the simplest method for determining values on a graph between two points connected by a straight line. This process is performed by drawing a straight line between two known points [10], for example, points A and E. Subsequently, by drawing a line through the known data points, x and $f(x)$, a relationship can be observed between two similar triangles, namely triangles ABC and ADE, where the relationship is expressed in Equation (1).

$$\frac{BC}{AB} = \frac{DE}{AD} \tag{1}$$

Figure 1 illustrates the graph of linear interpolation.

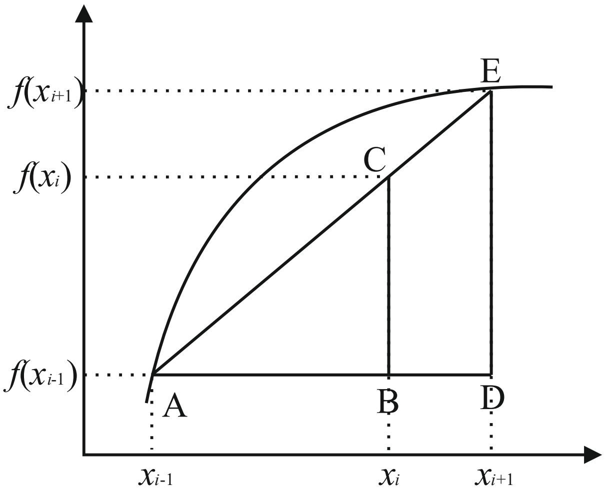

Fig. 1. linear interpolation

From Equation (1), a new equation can be derived through Figure 1, resulting in Equation (2) as follows:

$$f(x_i) = f(x_{i-1}) + \frac{f(x_{i+1}) - f(x_{i-1})}{x_{i+1} - x_{i-1}} f(x - x_{i-1}) \tag{2}$$

The explanation of Equation (2) is as follows [11]:

$f(x_i)$: The value on the Y-axis corresponding to the value xix_i on the X-axis being sought.

$f(x_{i-1})$: The value on the Y-axis corresponding to the value xi−1x_{i-1} on the X-axis, representing the position of the point on the left.

$f(x_{i+1})$: The value on the Y-axis corresponding to the value xi+1x_{i+1} on the X-axis, representing the position of the point on the right.

x_{i-1} : The position of the point on the left along the X-axis.

x_{i+1} : The position of the point on the right along the X-axis.

x_i : The position of the point being sought on the X-axis.

In general, the smaller the interval between data points, the better the approximation. This characteristic is demonstrated in the following example:

In the example below, we will estimate the natural logarithm of Z (ln Z) using linear

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interpolation. The first step is to perform the interpolation computation between ln 1 = 0 and ln 6 = 1.7917595 as follows:

$$f_t(2) = 0 + \frac{1{,}7917595 - 0}{6 - 1}(2 - 1) = 0{,}35835190 \quad (2)$$

This indicates an error percentage of e t = 48.3%. By using a smaller interval from x0 = 1 to x1 = 4, the following calculation is obtained:

$$ft(2) = 0 + \frac{1{,}3862944 - 0}{4 - 1}(2 - 1) = 0{,}469209813 \quad (3)$$

Thus, by using a shorter interval, the relative error percentage is reduced to e_t = 33.3%.

2.5. Profile Matching Model

The Profile Matching method is a commonly used technique in decision-making, which assumes the existence of an ideal level of predictor variables that must be met by the subjects being studied, rather than merely a minimum level [11]. In general, Profile Matching is the process of comparing the actual data values of an assessed profile with the expected profile values to identify the differences in competencies (known as gaps). The smaller the resulting gap, the higher the weight of its value.

Here are some formulations and stages of calculation using the Profile Matching method:

1. Mapping the gap values

Competency gap mapping is carried out by identifying the differences between the attribute profile and the target profile. The difference or gap between these two profiles can be calculated using Equation (3).

$$Gap = Value\ Atribut - Value\ Target \quad (3)$$

2. Weighting.

Determining the weight of the competency gap values. In this stage, the weight of each gap value will be determined by referring to Table 1, which shows the weight of the GAP values.

Tabel 1. GAP value weight [9]

No.	GAP differenc e	Value weight	Description
1.	0	4	Competency as required
2.	1	3.5	Individual competency exceeds 1 level
3.	-1	3	Individual competency is 1 level below
4.	2	2.5	Individual competency exceeds 2 levels
5.	-2	2	Individual competency is 2 levels below
6.	3	1.5	Individual competency exceeds 3 levels
7.	-3	1	Individual competency is 3 levels below

3. *Core* and *Secondary Factor*.

At this stage, the value for each aspect of the core factor and secondary factor will be determined.

a. *The core factor is the most prominent/most needed aspect (competency) of a position, which is expected to yield optimal performance*.

b. *The secondary factor refers to items other than the aspects present in the core factor*.

4. Calculation of Total Value.

The total value of all aspects is calculated based on the average of the core factor and secondary factor, with the weights for each factor being predetermined, i.e., 60% for the core factor and 40% for the secondary factor. Equation (4) is used to calculate the total value.

$$N = (x)\%.NCF + (x)\%.NSF \quad (4)$$

Explanation:

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N : Total value
x : Percentage value
NCF: *Core factor value*
NSF: *Secondary factor value*

5. Ranking.

Determining the ranking value. The final result of the Profile Matching model calculation process is to calculate the ranking of the offered positions. The ranking can be determined using Equation (5).

$$Rangking = ((x_1).N_1) + ((x_2).N_2) + \cdots + ((x_n).N_n) \quad (5)$$

Explanation:
x : The weight assigned to each parameter.
N_1 : Final value of parameter 1
N_2 : Final value of parameter 2
N_n : Final value of parameter n

2.6. Modified Profile Matching Model

The modified Profile Matching method is a profile matching approach that does not involve calculations using GAP value mapping, GAP value weighting, core factor, secondary factor, and total value calculation. The calculations are based on proximity values found in qualitative data and linear interpolation functions in quantitative data, with weighting applied to the suitability classes shown in Table 2.

Table 2. Suitability class

Type	Suitability class	Weight
Highly suitable	S1	3
Fairly suitable	S2	2
Marginally suitable	S3	1
Not suitable	N	0

In determining the score in the modified Profile Matching model, direct weighting is applied using the suitability class for proximity values and **Equation (2)** for the linear interpolation function. The results from both calculations then generate a ranking score using **Equation (6).**

$$SR_j = \sum_{i=1}^{m}(x_{ij}) \quad (6)$$

Explanation:
SR_j= Ranking score or total sum of the elements in column j.
x_{ij}= Matrix element in row i and column j.

The decision model process is the process of modeling a decision support system for selecting coffee crops for a specific land based on the steps of each decision method with input data from the relevant experts. Figure 2 illustrates the decision model process of the decision support system for selecting coffee crops for a specific land.

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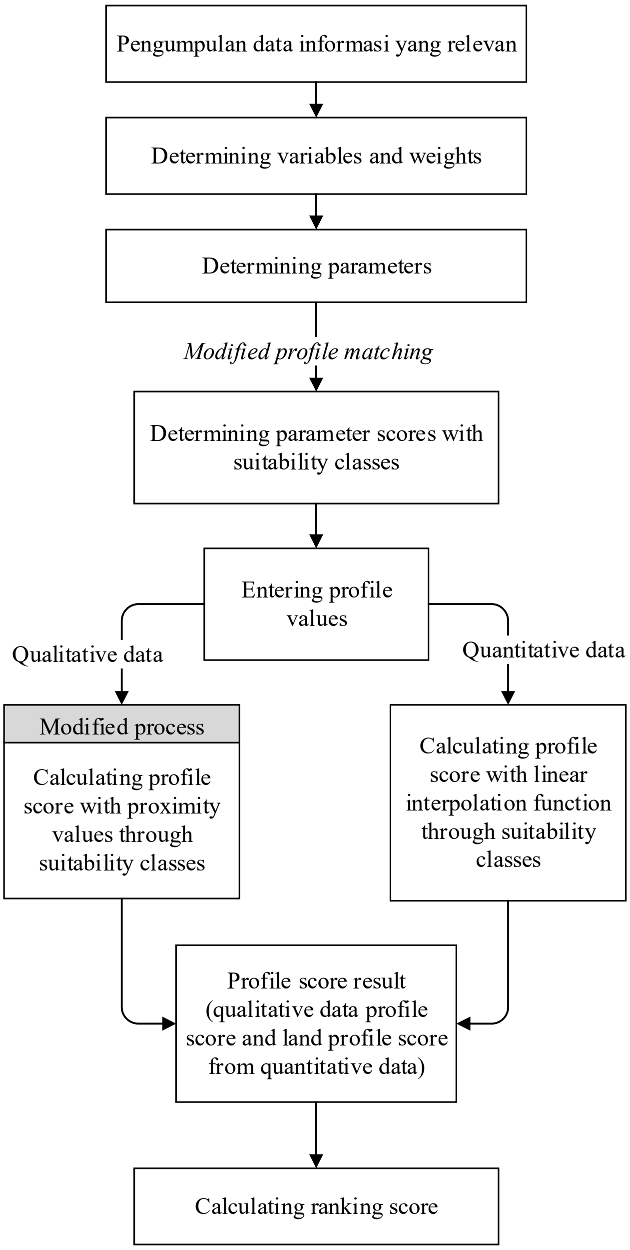

Fig. 2. Decision model process for selecting coffee crops for a specific land.

3. Results and Discussion

The calculation is carried out in several stages. In the initial stage, relevant data regarding the land characteristics are identified. Next, the calculation process is performed using the modified profile matching method. Land characteristic data from eight sub-districts are entered, and the profile matching scores are calculated based on scoring through suitability classes. For qualitative data, the values are calculated based on proximity, while for quantitative data, a linear interpolation function is used. Then, each value obtained is summed in each column to obtain the final score, which is used as the basis for ranking and recommending the most suitable type of coffee plant for the land characteristics.

Land suitability refers to the degree of appropriateness of a land area for a specific use. For example, land is highly suitable for irrigation, moderately suitable for perennial crop farming, or annual crop farming. Specifically, land suitability can be assessed based on the physical properties of its environment, including climate, soil, topography, hydrology, and/or drainage, which are suitable for a specific agricultural activity or a productive commodity [3].

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An example of the implementation of the temperature function (TC) on Arabica coffee plants can be seen in the following Figure 3:

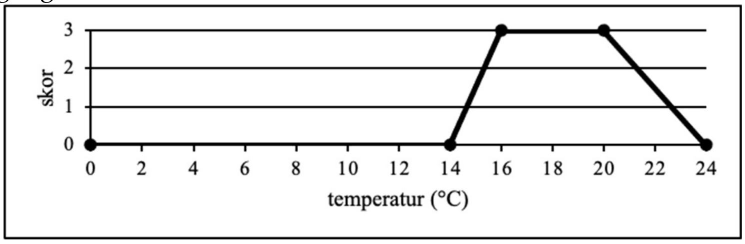

Fig. 3. The temperature function of Arabica coffee

The calculation of the temperature function from Figure 3 can be calculated using Equation (2), and the results are as follows:

$$TC(x) = \begin{cases} 0, & 14 > x > 24 \\ 0 + \dfrac{(3-0)}{(16-14)}(x-14), & 14 \le x \le 16 \\ 3, & 16 < x < 20 \\ 0 + \dfrac{(3-0)}{(24-20)}(24-x), & 20 \le x \le 24 \end{cases}$$

The following is Table 3, which outlines land data for land suitability assessment with qualitative data, and Table 4, which relates to land data for quantitative land suitability assessment.

Table 3. Qualitative Data Assessment

Land data for qualitative land suitability assessment		
Land	**DR**	**TT**
AIKMEL	good	slightly more refined
MASBAGIK	good	slightly more refined
MONTONG GADING	good	slightly more refined
PRINGGASELA	good	slightly more refined
SEMBALUN	good	moderate
SIKUR	good	slightly more refined
SUELA	good	slightly more refined
WANASABA	good	slightly more refined

Table 4. Quantitative Land Assessment

Land data for quantitative land suitability assessment											
Land	TC	CH	KU	EL	KE	LR	KT	KB	PH	CO	KN
AIKMEL	26,4	113,65	83,37	450	120	6	13	100	6	1,84	0,21
MASBAGIK	26,4	115,85	83,37	250	120	6	13	100	6	1,84	0,21
MONTONG GADING	26,4	156,03	83,37	450	120	20	40	100	6,5	1,11	0,12
PRINGGAS ELA	26,4	113,65	83,37	450	120	6	13	100	6	1,84	0,21
SEMBALUN	26,4	181,37	83,37	1000	120	6	17	100	6,5	1,48	0,15
SIKUR	26,4	139,37	83,37	250	120	6	17	100	6,5	1,11	0,12
SUELA	26,4	111,37	83,37	600	120	35	18	100	6,3	0,98	0,09
WANASAB A	26,4	111,37	83,37	450	120	6	17	100	6,5	1,11	0,12

The implementation of linear interpolation in the calculation of quantitative data from the suitability classes to obtain the score value for coffee plants, as implemented for Arabica coffee plants, can be seen in the following Table 5.

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Table 5. Results of scoring determination for qualitative data of Arabica coffee plants based on proximity values

Land	Arabica Coffee	
	drainage	Soil texture
AIKMEL	3,00	2,00
MASBAGIK	3,00	2,00
MONTONG GADING	3,00	2,00
PRINGGASELA	3,00	2,00
SEMBALUN	3,00	2,00
SIKUR	3,00	2,00
SUELA	3,00	2,00
WANASABA	3,00	2,00

Table 6 presents the results of the calculation for quantitative data using the linear interpolation implementation for Arabica coffee.

Table 6. Results of the scoring calculation for quantitative data of Arabica coffee.

Land	Results of the determination of the weight for Arabica coffee plants.										
	C	H	U	L	E	R	T	B	H	O	N
AIKMEL	,00	,00	,99	,00	,00	,00	,45	,00	,00	,73	,00
MASBAGIK	,00	,00	,99	,00	,00	,00	,45	,00	,00	,73	,00
MONTONG GADING	,00	,00	,99	,00	,00	,36	,00	,00	,00	,52	,36
PRINGGASELA	,00	,00	,99	,00	,00	,00	,45	,00	,00	,73	,00
SEMBALUN	,00	,00	,99	,00	,00	,00	,00	,00	,00	,13	,91
SIKUR	,00	,00	,99	,00	,00	,00	,00	,00	,00	,52	,36
SUELA	,00	,00	,99	,00	,00	,00	,00	,00	,00	,30	,00
WANASABA	,00	,00	,99	,00	,00	,00	,00	,00	,00	,52	,36

Calculation Results

The ranking calculation results from the calculations built using the modified profile matching method, based on input data from experts at Politeknik LPP Yogyakarta, can be seen in Table 7 below:

Table 7. Coffee Plant Ranking Score Results

Sub-district	RANKING		
	1	2	3
Aikmel	Liberica	Robusta	Arabica
Masbagik	Liberica	Robusta	Arabica
Montong Gading	Liberica	Robusta	Arabica
Pringgasela	Liberica	Robusta	Arabica
Sembalun	Liberica	Arabica	Robusta
Sikur	Liberica	Robusta	Arabica
Suela	Liberica	Robusta	Arabica
Wanasaba	Liberica	Robusta	Arabica

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3.1 Discussion

Based on the results of the testing, as seen from the ranking scores in Table 3, the output data from the modified profile matching method, which uses proximity value calculations and linear interpolation functions, shows that the ranking score for Liberica coffee is recommended as the 1st rank in the 8 sub-districts: Aikmel, Masbagik, Montong Gading, Pringgasela, Sembalun, Sikur, Suela, and Wanasaba. Meanwhile, Robusta coffee ranks second in the sub-districts of Aikmel, Masbagik, Montong Gading, Pringgasela, Sikur, Suela, and Wanasaba. On the other hand, Arabica coffee ranks third in the sub-districts of Aikmel, Masbagik, Montong Gading, Pringgasela, Sikur, Suela, and Wanasaba.

4. Conclusion

Based on the results of the research conducted, the modified profile matching method was able to generate a ranking of coffee plants that is suitable for the land in East Lombok Regency. In this modified profile matching method, qualitative data used proximity values through suitability classes for drainage and soil texture characteristics, while for quantitative data, calculations were made using the linear interpolation function through suitability classes for temperature, rainfall, humidity, elevation, effective soil depth, slope, cation exchange capacity (CEC), base saturation, pH H2O, organic carbon content (C-organic), and nitrogen (N) characteristics. The ranking results obtained from this study showed that Liberica coffee ranked 1st in all sub-districts, Robusta coffee ranked 2nd in 7 sub-districts and 3rd in Sembalun sub-district, and finally, Arabica coffee ranked 3rd in 7 sub-districts and 2nd in Sembalun sub-district.

Author Contributions

Description of the Author's Contribution in the Research on Coffee Plant Suitability Using a Modified Profile Matching Method

In the research on land suitability for coffee plants using a modified Profile Matching method, the author's contributions encompass several key aspects:

Development of a Land Suitability Evaluation Model

1. The author adapts the Profile Matching method, which is commonly used in selection and decision-making processes, to assess land suitability for coffee cultivation.
2. Modifications are made by incorporating agroecological factors such as altitude, slope gradient, soil type, rainfall, temperature, and soil fertility as the primary variables in the suitability assessment.

Weight Adjustment and Factor Weighting

1. In the Profile Matching method, a gap (difference) is measured between the ideal and actual conditions.
2. The author proposes weight adjustments for each land parameter based on its influence on coffee growth (e.g., an optimal temperature of 18–24°C is given higher weight than other factors).
3. Further modifications integrate fuzzy logic or machine learning techniques to enhance the accuracy of the analysis results.

Validation and Testing of the Model in Study Locations

1. The author applies the model to specific study locations, such as highland areas for Arabica coffee or mid-altitude regions for Robusta coffee.
2. Data collected from field observations, satellite imagery, or soil laboratory tests are used as inputs to validate the accuracy of the modified model.
3. The evaluation results are compared with conventional methods (e.g., FAO guidelines or the Analytical Hierarchy Process) to highlight the advantages and limitations of the modified Profile Matching approach.

Development of a Decision Support System (DSS)

1. The author contributes to developing a computer-based system to automate the land suitability analysis process.
2. By utilizing the algorithm from the modified Profile Matching method, the system can quickly and accurately recommend the best locations for coffee cultivation.

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Publication and Implications for Farmers and Policymakers

1. This research benefits coffee farmers by helping them select the most optimal land to improve yield and production quality.
2. The findings can also be utilized by governments or agribusiness companies in formulating sustainable coffee plantation development strategies.
3. With the modifications in the Profile Matching method, this research offers a more flexible and data-driven approach to land suitability assessment for coffee plants, compared to conventional, more static methods.

This contribution enhances the precision and applicability of land suitability analysis, providing a valuable tool for stakeholders in the coffee industry.

Declaration of Competing Interest

We declare that we have no conflict of interest.

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