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Assessment of farmers' preferences for growing particular crops and the correlation with land suitability

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Abstract: The success of agricultural operations is highly dependent on the site selected, which affects sustainability, and it is important to solve problems associated with activities and efficient land use. However, many researchers have selected sites based solely on climate and soil characteristics and have ignored farmer preferences, which has resulted in the failure to meet sustainable agriculture goals, and a proper strategy is therefore required to anticipate related problems. This study was conducted to: (1) analyze plantation development priorities based on the hierarchy of farmers' preferences, (2) identify the relationship between successful plantations, climate, and soil fertility. The attributes employed to assess farmers' preferences included price, production, and price stability over the past five years, while annual rainfall, annual temperature, and soil fertility were used to assess land suitability. Farmers' preferences were analyzed using the discrete choice experiment (DCE) method, and land suitability was analyzed using the fuzzy method. The farmer preference analysis showed that coffee was the priority crop of farmers in most of the research areas, and cocoa was the lowest cultivation priority. Coffee had a higher land suitability index than other plants, ranging from 0.62 to 0.92, and it was dominant within the optimal suitability class. Clove, pepper, and cocoa plants belonged to the moderate land suitability class with indexes of 0.6–0.91, 0.56–0.88, and 0.4–0.86 for pepper, clove, and cocoa, respectively. A regression analysis was conducted to determine the relationship between the priority of cultivated plants based on farmers' preference and land suitability, and a positive relationship (moderate strength) was determined. These research results show that when selecting priority crops, 21% of farmers' decisions are influenced by land suitability.

Keywords: *agricultural land management, crop diversification, land suitability, farmer's preferences, discrete choice experiments, fuzzy method, the analytic hierarchy process.*

Introduction

When designing policies for sustainable agriculture, the preferences of farmers cannot be ignored, and they are ultimately the final decision makers. Sustainable farms can only be realized by considering the cropping priorities of farmers, and these are usually related to local knowledge and the culture of a region

However, it has been said that traditional farmers ignore environmental suitability when selecting suitable crops for cultivation (Example: Yusianto et al., 2020). Farmers are mainly concerned about resource productivity and profit, and they carefully consider resource use decisions to achieve both goals (Kahan, 2008). According to Antiwi et al. (2022) and Taghizadeh et al. (2020), an appropriate land type is necessary to achieve high crop production; therefore, crop selection by farmers is also inadvertently based on soil suitability.

The study of Feizizadeh and Blaschke (2013) was based on the hypothesis it would be sensible and appropriate to incorporate farmers' knowledge into the process. However, recent studies have shown that the assessment of sustainable agriculture focuses only on ecological and economic aspects while ignoring social aspects, such as farmer preferences. A systematic review by Gebre et al. (2021) presents a report comparing the percentage of publications from 2000 to 2018 that focus on four aspects of sustainability: economical, ecological, social, and technical. They explained that 40.6% of publications globally only consider environmental aspects, while the other 26% consider a combination of environmental and economic aspects. Only 13% of the publications consider social aspects, and even less consider technical aspects. Many land allocation studies only aim to meet only ecological and economic dimensions, and the most commonly used pillars are the environmental, economic, and social pillars, which are equally crucial in decision-making.

Farmers should be recognized as the most influential decision-makers in the implementation of agriculture. Farmers select crops with the highest value based on plant attributes or considering production volumes and market demands or prices. Their growing preferences are based on profit and are influenced by many factors, including socioeconomic and psychological conditions. Several studies have shown that different agents and drivers of regional development are successful factors in implementing agricultural development programs. In addition, accepting farmers' preferences results in their acceptability and ability to grow crops properly. Identifying crop priority preferences allows various stakeholders, including governments and experts, to develop trade and communication strategies that maximize agricultural land development (Eitzinger et al., 2018).

The aim of current sustainable agriculture is to ensure future sustainability. However, due to the influence of internal factors, the decisions made do not always correspond with the predictions of experts and the modeling process conducted. According to Acheampong et al. (2018), crops are grown to meet particular needs, which affect land allocation decisions, and crop utility is maximized by selecting the most useful crop to cultivate. Farmers select a product based on its characteristics, which influences decision-making.

Farmers' preferences for plantation crops can be analyzed using a discrete choice experiment (DCE) approach, and factors influencing farmers' decisions can be identified, in addition to their preferences, which affect various considerations known as selection attributes. The DCE approach shows how the traits of individual cultivars are evaluated and selected from multiple alternative crops, and selecting such a cultivar is based on multiple hypotheses (Hoyos, 2010). The study provides the opportunity to predict how farmers will evaluate development programs designed in agricultural areas. Finally, the DCE approach is a state-of-preferences approach in which the respondent expresses the choice or decision directly.

Farmer preferences and the suitability of growing crops in a particular environment need to be addressed when developing strategies to develop sustainable agricultural land. Assessing soil suitability is one of the most critical aspects of designing sustainable agriculture, and assessing land suitability is necessary to ensure current and future food security through the efficient use of land resources. The suitability of a particular type of land for a particular purpose is determined by evaluating the climate, soil, and topographical components and understanding the biophysical constraints. It is thus crucial to assess the suitability of agricultural land to increase production and plan a sustainable agricultural system (Taghizadeh et al., 2020), and the suitability of land for certain agricultural activities promotes the production. Farmer income is closely linked to agricultural production, which influences the decision by farmers to support sustainable agriculture (Pieiro et al., 2020). Due to the large number of factors considered in the process, land suitability assessments are commonly referred to as multicriteria (MC) assessments. Conducting such an analysis needs to consider the climate, hydrology, topography, vegetation, and soil properties (Cartwright et al., 2020). Conducting a soil suitability assessment via an MC assessment is a decision-making aid for use in dealing with contradictory criteria. There are two things to consider when assessing soil suitability based on MC: the alignment of the assessment unit and assessing conflicts of interest between multiple attributes. The membership values and the weight of the indicators have a significant impact on the results of the MCDM land suitability assessment. To solve these two main problems, the using a combination of fuzzy and analytic hierarchy processes (AHP) could be an alternative solution.

Physical factors, such as climate and soil fertility, cannot be separated from the preferences of farmers when designing sustainable agriculture. Conventional farming, which is based on the opinions of farmers, potentially causes environmental problems, whereas sustainable farming, which only considers environmental aspects and ignores farmers' preferences, has the potential to affect the sustainability of a farm. Therefore, farmers' preferences should be considered when adopting a proposed planning program. Land suitability is a critical issue that needs to be addressed with respect to current and future food security, and the efficient use of land resources is required to reduce the amount of environmental damage associated with inappropriate land use.

These two aspects are equally important when designing sustainable agriculture solutions and they cannot be separated from each other.

This study aims to determine the relationship between farmers' preferences for growing a particular crop and land suitability.

Research methods

This study was conducted in Enrekang, a district in South Sulawesi, Indonesia, that comprises 12 administrative subdistricts. The area is located at an elevation of 473,293 meters above sea level, and it lies between 3°14'36" and 3°50'0" south latitude and between 19°40'53" and 120°06'33" east longitude.

This study integrates three different research methodologies: (1) an assessment of farmers' preferences for priority crops using the DCE method, (2) an assessment of soil suitability using the fuzzy method and AHP method, (3) the interrelated selection of priority crops based on farmers' preferences for arable land suitability.

Farmer preference assessment

Rating attributes

This analysis was conducted to determine farmers' preferences for selecting a potential crop. Each respondent was asked to rank their preferred crop according to their selection criteria. The DCE method has been widely used to determine the preferences of different objects, and we used this approach to assess farmers' preferences for growing five crops. Farmers were presented with a hypothetical setting and asked to choose (typically iteratively) between a number of alternatives. DCE is a quantitative method used to determine the preferences of informants by querying their particular choices based on the attributes of the object under study. In this case, the farmers were presented with several options and asked to choose from a choice set, where the choice set was a set of hypotheses built on the attributes of plantation crops.

The stages of the DCE used in this study were employed to determine the attributes and levels. The factors used in this study included price and production, and price and production stability over five years. According to the preliminary survey, these factors were considered to be the most important factors influencing farmers' decisions. Some of these factors have also been used in several studies. For example, Asrat et al. (2009) found that environmental adaptability and yield stability were the most important variables influencing the choice of agricultural crop varieties; The study also determined that household resources (particularly land and property ownership), the farmer's experience, and exposure to advisers were the main factors leading to preference heterogeneity (Asrat et al., 2009).

The level of each criterion used was based on the state of the basic criteria at the study site. Therefore, it was essential to conduct a preliminary site survey before determining the attribute level. Price and production levels were based on 10 years or data collected from respondents and previous on-site studies, and these were the highest and lowest values reached in the last 10 years. Table 1 contains a complete description of the attributes used and their descriptions.

Table 1 - Attributes used to assess farmers' preferences for selecting plants to cultivate

Attribute	Description
Price commodity	The amount of money (IDR) the farmer earns by selling 1 kg of the commodity
Amount produced	Amount harvested from one hectare
Stability price	The price stability of a crop from year to year over 5 years
Stability results	Does the variety provide stable yields, even though environmental change, disease, or plant pests occur?

Table 2 - Attributes and levels used to evaluate farmers' preferences

Attribute level	Attribute			
	Price (IDR)/kg	Production	Stability price	Stability results
Coffee	[1] 18000 [2] 22000 [3] 38000	[1] 600 [2] 700 [3] 900	[1] Drop in selling prices from year to year; [2] Stable selling price from year to year	[1] Plant type associated with an unstable price that tends to fall from year to year; [2] Plant type associated with a stable price from year to year
Cocoa	[1] 19000 [2] 25000 [3] 35000	[1] 500 [2] 700 [3] 900	[1] Drop in selling prices from year to year; [2] Stable selling price from year to year	[1] Plant type associated with an unstable price that tends to fall from year to year; [2] Plant type associated with a stable price from year to year
Clove	[1] 40000 [2] 75000 [3] 120000	[1] 500 [2] 600 [3] 800	[1] Drop in selling price from year to year; [2] Stable selling price- from year to year	[1] Plant type associated with an unstable price that tends to fall from year to year; [2] Plant type associated with a stable price from year to year
Pepper	[1] 35000 [2] 45000 [3] 60000	[1] 400 [2] 500 [3] 600	[1] Drop in selling price from year to year; [2] Stable selling price from year to year	[1] Plant type associated with an unstable price that tends to fall from year to year; [2] Plant type associated with stable price from year to year

The attributes and levels comprise several concepts that the respondents can select according to their preferences, and they can be altered within a choice set. The concepts in the choice set were formed by random design (semi-orthogonal) using the R Studio application. The coffee attribute is shown in Figure 1 as an example.

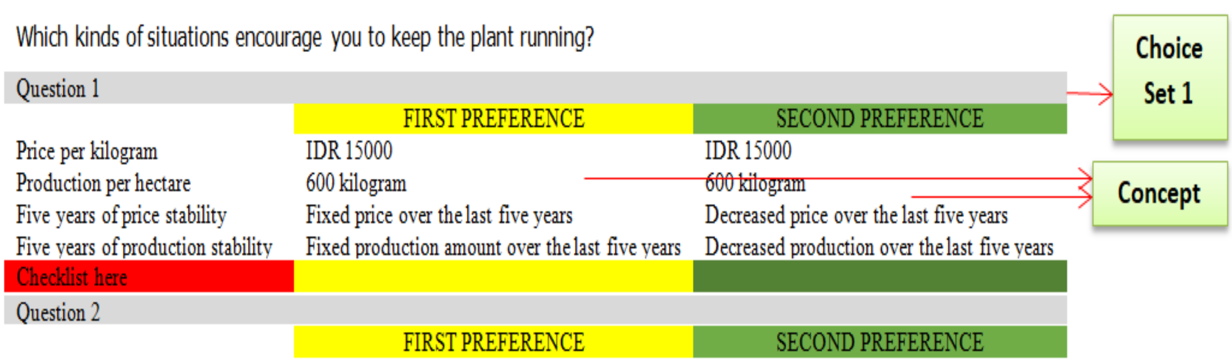

Figure 1 - Example of choice set used in this study

The choice set was built using the RStudio Desktop application (open-source license). In a complete factorial calculation, 16 concepts and eight selection sets were formed from all culture levels and attributes. Each attribute was associated with two levels. Respondents lose interest when asked too many questions or when there are too many concepts associated with the choices offered, which compromises the results and reduces the utility of the study. There are no restrictions on the number of concepts that should be applied in the selection set. As an increased number of concepts in the choice set confuses informants, 16 with eight choices are used.

Sample size and respondent criteria

According to the rule of Faust's principle (Johnson & Orme, 2003), the minimum number of samples was set to 63. Furthermore, Faust's principle states that the sample size required in the DCE depends on the number of choices (t), the choices (a), and the highest overall level of attributes used (c), and is expressed by Equation 1,

$$N \geq \frac{500\,c}{t.a} \qquad (1)$$

Lancsar and Louviere (2008) stated that practical experience showed that studies rarely require more than 20 respondents for a single questionnaire to create a reliable model. However, a larger sample size is always required when performing a post hoc analysis to identify and estimate the effect of covariates. Nevertheless, according to Issac & Michael (1995), a small sample size can be justified in exploratory cases and pilot studies. Analogous to the study of Issac and Michael (1995), Gay & Diehl (1992) also found that the number of acceptable respondents is generally dependent on the study type and whether the study is experimental. In this study, the minimum number of eligible respondents was set to 30, and 30 samples were obtained for 12 subdistricts (total number of 360).

The respondents in this study were farmers who cultivate analyzed crops are still cultivating plantation crops up to now. Each respondent is allowed to answer eight choices for one type of plant, even though farmers have more from one cultivated plantation crop. The total number of respondents who becomes an object study was 360 people, spread over 12 subdistricts. Data collection from respondents was conducted through questionnaires and in-depth interviews. The characteristics of all respondents are described in Figures 2 and 3.

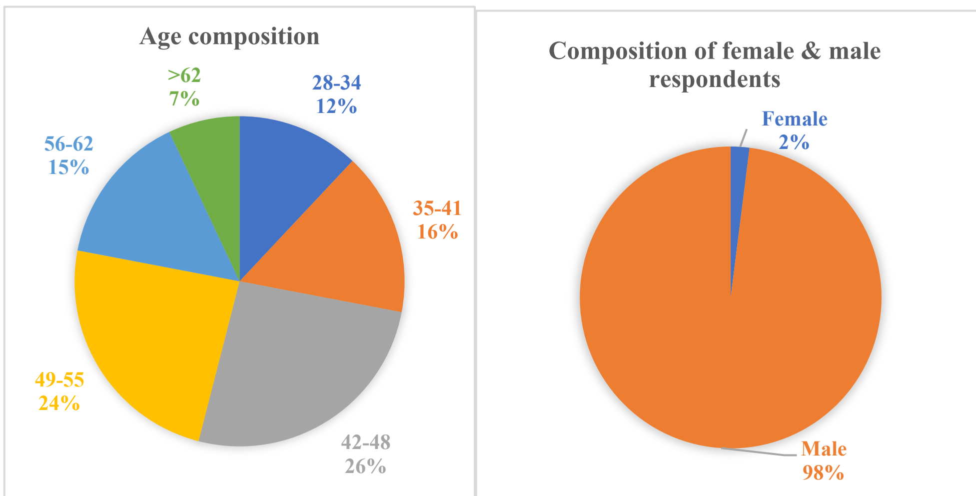

Figure 2 - Demographics of respondents based on sex and age

Figure 2 shows that 98% of respondents were male and only 2% were female. In addition, 50% of respondents were aged between 42 and 55 years; 12% were aged between 28 and 34 years; and 16% were aged between 35 and 41 years.

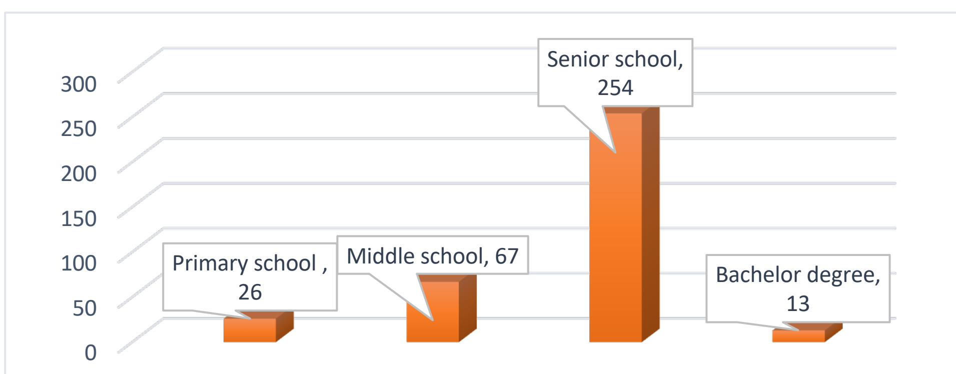

Figure 3 - Demographics of respondents based on level of education achieved

Based on the level of education achieved (Figure 3), 70.56% finished senior high school; 18.61% finished junior high school, and 7.22% and 3.61% finished elementary school and obtained a bachelor degree, respectively. Therefore, most farmers in Regency Enrekang had completed senior high school.

Farmer preference analysis

This study describes the cultivation preferences of farmers in terms of values, and this was also studied by Asrat, Yesuf, Carlsson & Wale (2009). McFadden's (1973) utility function is generally used to analyze the different responses and decisions of crops cultivars. The use of alternative i in choice t by farmer x, was predicted using Equation 2,

$$U_{itx} = \beta' A_{it} + \gamma price_{it} + \varepsilon_{it}, \qquad (2)$$

where $\beta' A_{it}$ is a constant of the valuation attributes other than price; $price_{it}$ is the price attribute for alternative i in choice t; γ is the marginal price of alternative i in choice t; and ε_{it} is the error component (the unobserved component). The probability that individual x chooses alternative i was predicted using Equation 3,

$$Pitx = \{\beta' A_{it} + \gamma price_{it} + \varepsilon it > \beta' A_{it} + \gamma price_{it} + \varepsilon_{it;}\ \forall j \neq i\}. \qquad (3)$$

In the analysis, non-monetary attributes are usually distributed using the logit random parameter model. The utility is described in Equation 3 as the willingness to pay (WTP). The concept of the WTP and how it is measured have been widely researched, especially with respect to the value of non-traded goods and services.

The theory of mean marginal WTP was introduced by Haneman (1984). Assuming that the utility function is linearly related to income, the utility function of a respondent can be assumed using the following equation,

$$U\,(Y, X, Q) + \varepsilon, (4)$$

where Y, X, Q, and ε are income, socioeconomic characteristics, environmental assets, and the error term, respectively. Suppose a respondent is offered an amount of money (A) for a change in Q_0 to Q_1, then the offer will be accepted when

$$U\,(Y - A, X, Q_1) + \varepsilon \geq U\,(Y, X, Q_0) + \varepsilon. \qquad (5)$$

This implies that a respondent's response can be a random variable with a cumulative distribution function (G) over the WTP to the amount A. Therefore, the probability that the cost of A could be accepted becomes

$$\text{Prob.}\{\text{accepted}\} = \text{Prob.}\{A \leq \text{WTP}) = 1 - \text{GWTP}\,(A). \qquad (6)$$

Wang and Whittington (2005) implemented the general concept of WTP with respect to environmental quality. Suppose an individual's utility value for environmental quality (E_0) is

$$V_0 = V(Y, P, E_0, Z, \varepsilon_1), \quad (7)$$

where Y is income, P is price, Z is socioeconomic variables, and ε_1 are other factors not included in Y, P, E0, and Z; at the point when the environmental quality level increases from E0 to E1, the individual utility changes to $V_1 = V(Y, P, E1, Z, \varepsilon_1)$. As it is assumed that individuals have a certain WTP for changes in environmental quality, the following equation is obtained,

$$V_0 = V\ (Y\text{-}WTP, P, E_1, Z, \varepsilon_1) = V_0 = V\ (Y, P, E_0, Z, \varepsilon_1). \qquad (8)$$

In this study, the mean marginal WTP for an attribute is the ratio of the coefficient to the marginal utility of the price, and it is modified by the following WTP model equation.

$$WTP = WTP\ (Y, E_0, E_1, Z, \varepsilon_1) = E\ [WTP] + \varepsilon. \qquad (9)$$

Land suitability assessment

The guidelines employed in the land suitability assessment were adapted from the Technical Guidelines for Land Assessment of Agricultural Commodities by Ritung et al. (2011) and the Guidelines for Area Assessment Part III on Plant Requirements by Sys (1993).

Evaluation variables and characteristics of the research location

A land unit map of the study area (Figure 4), which consisted of 15 land systems, served as the reference for soil sampling. This map combines information about the ecological principles of rock types, hydroclimate, landforms, soils, and organisms (Blasi et al., 2008). According to Zonneveld (1989), survey results, including a unit map, can be used as the basis for conducting a land assessment. Soil samples were obtained at random from each land unit. Undisturbed soil was chosen in this study to provide an overview of the physical properties of the soil within plots in relatively homogeneous areas. Plots were excluded from sampling if there were a cemetery, residential area, plantation area, or a non-community-administered area.

The three primary variables used in the assessment were climate, topography, and soil, comprising 10 sub-variables. The subsoil sample analysis involved texture and cation exchange capacity (CEC) analyses, and top soil samples were analyzed to obtain the pH, basic cations (including Ca, Mg, K, and Na), and base saturation. The texture, CEC, pH, sum of basic cations, base saturation, and C-organic content were analyzed in the Soil Chemistry Laboratory of Hasanuddin University, Indonesia.

The pH of the study site was found to be acidic (maximum 6.04). Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na) comprised the basic cations in a range of 4.1–8.88 cmol/kg. The base saturation ranged from 28.54% to 46.30%, which was relatively low. The CEC at the study site was classified as moderate, ranging from 12.14 to 19.22 cmol/kg. The C-organic content in the research area ranged from 1% to 2.46%. The variables are listed in Table 3.

Slope information was modeled using a digital elevation model and imagery obtained from the Shuttle Radar Topography Mission (SRTM). Data from the SRTM has been widely used to obtain slope information (Lixia et al., 2021). Precipitation data were obtained from the Precipitation Observatory, and their distribution was modeled using the Thiessen method, which has been used extensively to model precipitation distribution (Lee, Kim, and Jun 2018). The distribution of precipitation and slope information are shown in Figure 5. Based on the modeling performed, the slope at the study site was found to range from 0º to 54º, while annual precipitation ranged from 1394 mm/year to 2633 mm/year.

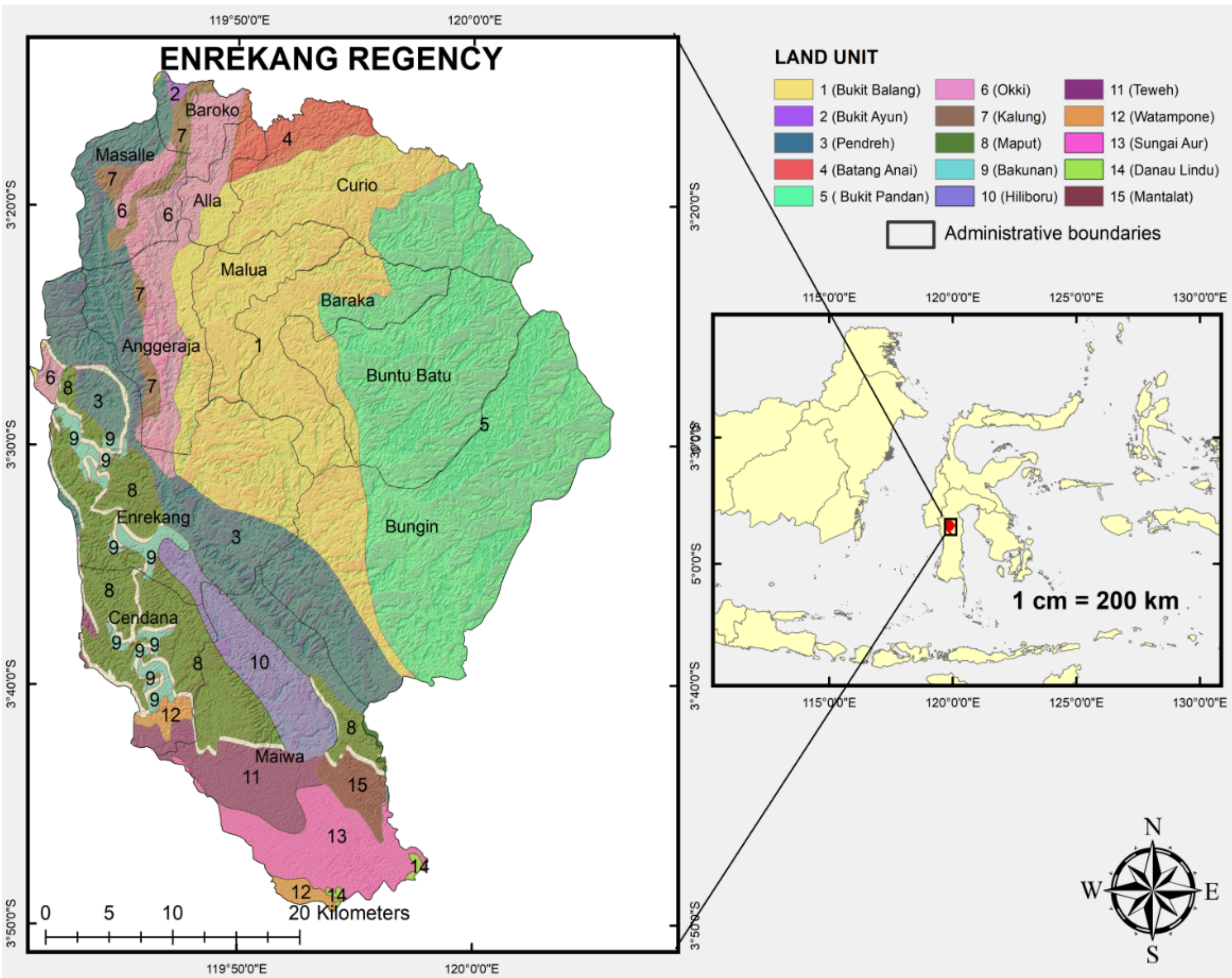

Figure 4 - Map of land units used as a reference for sampling

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Table 3 - Land characteristics of each land unit

Sub-variable/land characteristics	Land Unit														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sum of basic cations (cmol/kg)	5.88	4.63	5.79	6.93	5.73	4.55	8.88	5.06	4.21	5.03	4.10	4.84	4.83	5.90	5.36
Base saturation (%)	37.10	32.49	35.70	48.77	33.29	29.05	46.20	32.10	34.68	33.05	30.94	36.53	29.13	35.59	28.69
Organic matter (%)	1.46	0.68	1.38	1.38	0.72	1.68	2.46	1.59	1.42	1.32	1.42	0.72	1.26	2.42	1.18
Soil depth (cm)	120	120	130	110	150	150	150	130	100	130	110	120	90	100	90
Soil texture	0.00	0.00	2.00	0.00	0.00	0.00	2.00	0.00	2.00	2.00	1.00	1.00	1.00	0.00	1.00
pH	5.5	4.54	5.51	5.57	5.2	5.64	6.01	5.14	5.07	5.33	4.83	5.13	5.57	5.91	4.64
CEC (cmol/kg)	15.85	14.25	16.22	14.21	17.21	15.66	19.22	15.80	12.14	15.22	13.25	13.25	16.58	16.58	18.68
Annual temperature (°C)	25.00	25.00	25.00	27.00	27.00	25.00	21.00	26.00	27.00	26.00	28.00	28.00	27.00	27.00	27.00

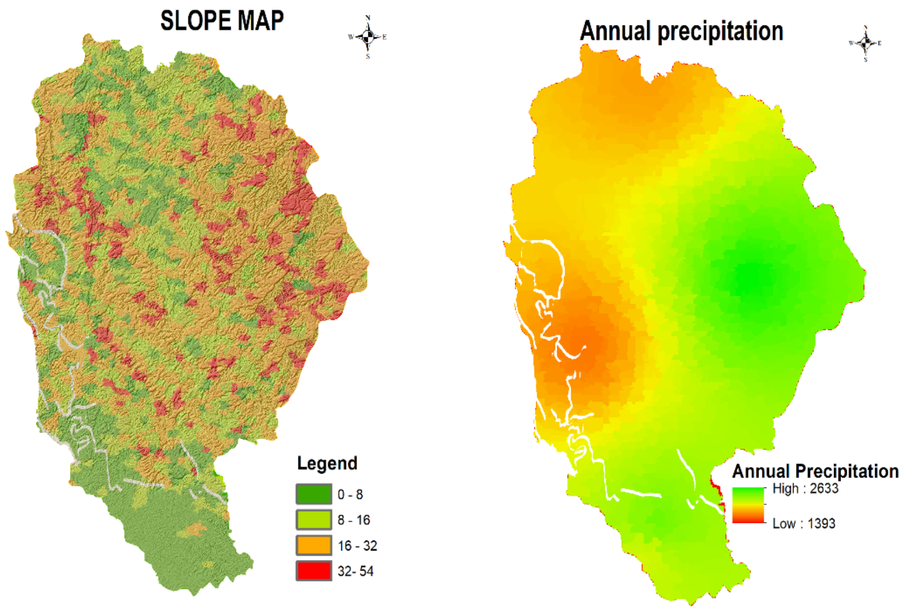

Figure 5 - Distribution of precipitation, slope in the protected areas and potential plantation development areas

Stage of the land suitability analysis

The fuzzy method by Zadeh (1965) was applied to analyze the land suitability for plantation crops in the entire study area. The fuzzy set approach used in this study was based on the semantic import model (SIM) used in land assessment. The SIM uses a functional approach, and a bell-shaped curve is employed to assess land performance characteristics with plant growth requirements. The fuzzy set function can continuously analyze soil properties without classifying them. In fuzzy analysis, land attribute values are converted to sustainable values ranging from 0 to 1. It is also necessary to consider several control points in fuzzy analysis, including the upper and lower threshold values (UCP and LCP), the optimal value (b), and the range of values between the optimal value and the threshold value, according to plant growing conditions. In this respect, b is the optimal soil properties for plant growth; UCP/LCP is the maximum and minimum threshold that can be tolerated when the value becomes a critical point for plant growth; and d is the range between b and UCP/LCP. As previously explained, the guidelines prepared by Sys were used to conduct the soil suitability assessment in this study, and the values of b, LCP/UCP, and d were therefore based on these guidelines.

When the soil attributes and critical points were determined, each soil attribute's membership value (MF) was calculated based on the characteristics of the land at the study site. To calculate the MF value, the land parameters tested were divided into two categories:

Slope and soil texture. The lower of slope and soil texture value, the more suitable for plant growth. The MF of this land attribute was calculated by Equation 10,

$$MF\,(x_i) = [1/(1 + \{(xi - b)/d_2)^2\ ], \text{ and } MF\,(x_i) = 1, \text{ if } xi \leq b; \qquad (10)$$

The sum of basic cations, pH, base saturation, soil organic matter, soil depth, CEC, annual precipitation, and temperature. Based on the properties of the soil at the research site, a higher soil attribute value implied that the soil was more suitable for plant growth. The MF of this land attribute was calculated by Equation 11,

$$MF(x_i) = [1/(1 + \{(xi - b)/d_1)^2], \text{ and } MF(x_i) = 1, \text{ if } xi \geq b. \quad (11)$$

The next important step was to determine the importance weight (w) of the parameters using the AHP method. To date, the AHP method has been widely used by researchers as a multi-attribute decision-making tool because of its ease of use and implementation (Keshavarzi et al., 2020; Nasery et al., 2021; Zalhaf et al., 2021 Kelic et al., 2022; Paul & Ghosh, 2022; Sengupta et al., 2022). The analytic hierarchy process calculates the weights for individual criterion using a pairwise comparison matrix by taking the eigenvalue corresponding to the highest eigenvector of the completed matrix and normalizing the sum of the factors to unity. The comparison matrix is mainly based on the reciprocity criterion, which is expressed as $n\ \frac{(n-1)}{2}$ for several n components in the pairwise comparison matrix. After the pairwise matrix has been calculated, relative weights are calculated using Saaty's method (Saaty, 1980). One the essential features of the analytical hierarchy process is that it identifies the inconsistencies of decision-makers. If the consistency ratio (CR) value is greater than 0.10, the matrix weight values indicate inconsistencies, and the method may not provide meaningful results (Saaty, 1980). Figure 6 shows the scores for the research criteria based on the calculation results using the AHP method.

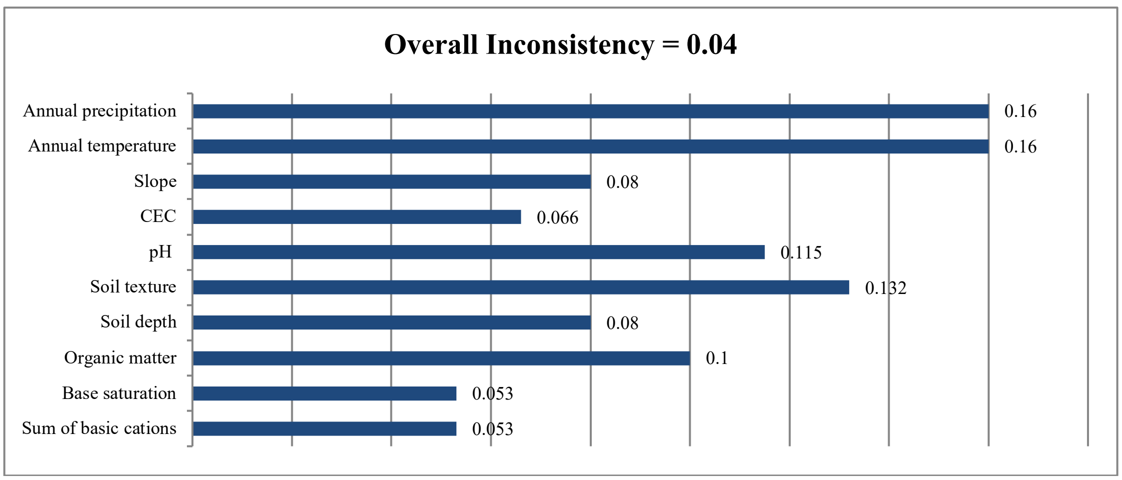

Figure 6 - Weighting of land suitability variables and comparative importance

The calculated CR in this study was 0.04, which was within the acceptable threshold values, and the calculated weight was therefore deemed to be acceptable.

The land suitability index (LSI) was calculated after all of the parameters of the land suitability assessment had been determined. For the LSI calculation, the MF of each factor was then integrated with the weight of the factor (W) using the equation,

$$LSI = \sum_{i=1}^{n} wi\ (MFxi) \quad (12)$$

Correlation between land suitability and farmer preferences

This study aimed to assess whether farmers' preferences in selecting priority crops were related to arable land suitability. In this respect, farmer's preference was considered to be the dependent variable and land suitability the independent variable. A correlation analysis was conducted to understand the relationship between the order of priority for four crops in 12 subdistricts (based on farmers' preferences) and the land suitability index for four crops in 15 land units. The Spearman rank correlation has been used by many researchers, such as Smith, Ashworth, and Owens (2022), to validate model results, and it was used here to analyze the relationship between land suitability and the preference of farmers for the priority order of these four crops. A significance value of <0.05 was required to determine a correlation between the land suitability index and farmer preferences. When conducting a correlation test, it is necessary to standardize the value to ensure that the weighting units of the two variables are equal. As the farmer preference and land suitability classes are ordinal data, a domain value must be specified prior to standardization. The value of the plantation crop area according to farmer's preferences is based on the priority order of the crops obtained via the DCE analysis. Priority 1, 2, 3, and 4 crops have domain values of 4, 3, 2, and 1, respectively. Likewise, for land suitability classes, land suitability class S1, S2, S3, and S4 have domain values of 4 3, 2, and 1, respectively. The domain and fuzzy membership values associated with crop priority order based on farmer preferences and soil suitability classes are presented in Table 4. The fuzzy membership standardization of both land suitability classes and farmer preferences was calculated using the equation

$$[Y] = \begin{cases} 0; & x \leq a \\ \frac{(x-a)}{(\mu-a)}; & a \leq x \leq \mu. \\ 1; & x \geq \mu \end{cases} \qquad (13)$$

Table 4 - Domain and fuzzy membership values

Suitability class	Domain value	Standardized value	Farmer Preference order	Domain value	Standardized value
S1	5	1	Priority 1	5	1
S2	4	.75	Priority 2	4	.75
S3	3	.50	Priority 3	4	.50
N1	2	.25	Priority 4	2	.25
N	1	0	No choice	2	0

Results and Discussion

Plant priority order based on farmers' preferences

The possibility of maintaining the growth of a crop and influential factors

The conditional logit method was used to express farmer preferences with respect to a set of alternatives for each individual, where the explanatory variables are the characteristics of the chosen alternative.

Table 5 - Results of modeling use by farmers against plant use attributes method conditional log

Alla								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	coef	p
Decreased production	−106	0.0000	−96.03	0.0001	−99.66	0.000568	−108.6	0.0033
Price continually decreases	−106	0.0000	−63.91	0.0001	−66.05	0.000568	−113.2	0.0033
Price	1.514	0.0000	0.213	0.0001	0.3302	0.000568	1,979	0.0033
Production	35.34	0.0000	95.86	0.0001	92.14	0.000568	34.67	0.0033
Rho-squared	0.75		0.73		0.66		0.31	
Anggeraja								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	coef	p
Decreased production	−102.9	0.0000	−110.9	0.0000	−292.5	0.0033	−60.63	0.0000
Price continually decreases	−108.1	0.0000	−102.8	0.0000	−173.6	0.0033	−275	0.0000
Price	1.544	0.0000	0.3426	0.0000	0.8679	0.0033	1.23	0.0000
Production	35.34	0.0000	53.02	0.0000	53.74	0.0033	43.55	0.0000
Rho-squared	0.78		0.77		0.78		0.78	
Baraka								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	coef	p
Decreased production	−107	0.0000	−105	0.0000	−102	0.0000	−29.25	0.0000
Price continually decreases	−105.4	0.0000	−106.7	0.0000	−108.7	0.0000	−17.36	0.0000
Price	1,505	0.0000	0.3556	0.0000	0.5437	0.0000	1.085	0.0000
Production	35.34	0.0000	53.01	0.0000	53.01	0.0000	35.82	0.0000
Rho-squared	0.75		0.75		0.78		0.84	
Barolo								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	coef	p
Decreased production	−113.2	0.0000	−29.25	0.0033	−101.7	0.0000	−75,325	0.0000
Price continually deceases	−101.3	0.0000	−173.6	0.0033	−94.5	0.0000	−67.36	0.0000
Price	1,447	0.0000	0.5786	0.0033	0.573	0.0000	1.24	0.0000
Production	35.36	0.0000	53.74	0.0033	51.03	0.0000	38.52	0.0000
Rho-squared	0.84		0.84		0.78		0.84	

Table 5 (coninues.)

Buntubatu								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−106	0.0033	−108.3	0.0026	−106	0.000	- 35.82	0.0033
Price continually decreases	−106	0.0033	−104.5	0.0026	−106	0.000	−17.6	0.0033
Price	1.514	0.0033	0.3483	0.0026	0.5301	0.000	−1.085	0.0033
Production	35.34	0.0033	53.01	0.0026	53.01	0.000	29.25	0.0033
Rho-squared	0.75		0.76		0.75		0.18	

Curio								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−101.2	0.0013	−132.2	0.0000	−103.8	0.000	−108	0.0000
Price continually decreases	−109.3	0.0013	−70.69	0.0000	−107.5	0.000	−165	0.0000
Price	1,561	0.0013	0.2356	0.0000	0.5376	0.000	4,856	0.0000
Production	35.35	0.0013	6,378	0.0000	53.01	0.000	77.04	0.0000
Rho-squared	0.8		0.68		0.78		0.61	

Malua								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−99.56	0.0010	−29.25	0.0000	−95.08	0.000	−96.21	0.0002
Price continually decreases	−63.67	0.0010	−173.6	0.0000	−70.81	0.000	−69.74	0.0002
Price	0.8787	0.0010	57.86	0.0000	0.3496	0.000	0.4291	0.0002
Production	62.95	0.0010	53.74	0.0000	89.67	0.000	60.13	0.0002
Rho-squared	0.64		0.74		0.75		0.72	

Marseille								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−69.31	0.0000	−208.3	0.0000	−102.9	0.000	−29.25	0.0033
Price continually decreases	−80.2	0.0000	−44.18	0.0000	−108.1	0.000	−173.6	0.0002
Price	5.452	0.0000	0.1473	0.0000	0.5404	0.000	1.085	0.0002
Production	67.05	0.0000	59.97	0.0000	53.01	0.000	35.82	0.0002
Rho-squared	0.56		0.8		0.76		0.8	

Table 5 (continues)

Burgin								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−97.65	0.0100	−97.65	0.0100	−103	0.041	−69.25	0.0000
Price continually decreases	−68.08	0.0100	−68.08	0.0100	−62.54	0.041	−63.6	0.0000
Price	0.9726	0.0100	0.2269	0.0100	0.3127	0.041	1.085	0.0000
Production	60.76	0.0100	91.13	0.0100	93.82	0.041	35.82	0.0000
Rho-squared	0.69		0.69		0.8		0.6	
Cendana								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−100.2	0.0010	−97.65	0.0100	−98.95	0.000	−79.25	0.0000
Price continually decreases	− 99.3	0.0010	−68.08	0.0100	−81.11	0.000	−173.6	0.0000
Price	1.654	0.0010	0.182	0.0100	0.5541	0.000	−1.085	0.0000
Production	23.23	0.0010	41.174	0.0100	53.03	0.000	−35.82	0.0000
Rho-squared	0.8		0.83		0.83		0.6	
Enrekang								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−208.3	0.0000	−91.18	0.0000	−98.95	0.000	−29.25	0.0000
Price continually decreases	−44.18	0.0000	−71.18	0.0000	−81.11	0.000	−173.6	0.0000
Price	0.6311	0.0000	0.3559	0.0000	0.5541	0.000	1.085	0.0000
Production	39.98	0.0000	9.131	0.0000	53.03	0.000	35.82	0.0000
Rho-squared	0.8		0.7		0.78		0.78	
Maiwa								
Attribute	Coffee		Clove		Pepper		Cocoa	
	coef	p	coef	p	coef	p	Coef	p
Decreased production	−29.25	0.0033	−101.1	0.0006	−96.88	0.000	−98.16	0.0000
Price continually decreases	−173.6	0.0033	−96.58	0.0006	−68.85	0.000	−111.4	0.0000
Price	2.48	0.0033	0.2219	0.0006	0.3442	0.000	0.696	0.0000
Production	25.82	0.0033	90.91	0.0006	60.75	0.000	35.36	0.0000
Rho-squared	0.8		0.67		0.72		0.85	

The analysis showed that the factors most influencing preferences were as follows: production stability in five years, stable price in five years, latest amount produced, and latest price. Factors considered influence farmers for permanent conserve plant plantations disclosed with score utility using conditional logit modeling developed by McFadden (1973). The farmer utility with the conditional logit modeling is shown in Table 5.

The output in Table 5 represents the responses of respondents to nine complex questions derived using the conditional logit method. The *choice set* consisted of the number of drafts given to respondents to make selections according to their preferences, and the concepts within the *choice_ set* were derived using a random design (semi-orthogonal) via the R studio application.The output in Table 5 represents the modeling results of farmers' choices. In this study, ᾱ =5%, provided that an attribute with a p-value >5% does not influence the twisting of cultivated plants. All of the attributes used had p-values <0.05; therefore, it was concluded that all of the attributes used influenced the preferences of farmers for selecting a particular plant for cultivation. In logit regression, the value of R^2 should be >15% to represent a good fit (Paul Allison, 2012). The model used provided R^2 >1 and a good fit was therefore verified. This also showed that the research attributes used influenced more than 15% of the factors that influenced the preference of farmers for selecting and maintaining a particular cultivated crops.

The results of the estimation model in Table 5 show that the factors that most affected the selection of plant cultivation by respondents in a row were production stability, price stability, the amount produced, and the price. Table 5 also shows that stable production had a greater influence on farmers' decisions to maintain a particular crop, because the coefficient values were higher than those of other attributes.

In the Alla district, the parameter values for environmental stability and price stability (with decreasing criteria) were negative (-), while those of production and price were positive (+). This indicates that the decline and drop in production over five years lowered the utility of these commodities to farmers by as much as 106 times. Based on the coefficient score, the farmers' decision to maintain coffee cultivation was dominantly influenced by its stable production and price. If production decreased over five years, it would reduce the utility of coffee to farmers by as much as 42%, even if the price remained stable. Farmers in Subdistrict Anggeraja were also dominated by production and price stability over the last five years when they made a decision. If a continuous decline in production and price occurred over five years, the utility of the crop to farmers would be reduced 100 times. The dominant influence of production stability and price stability in the Anggeraja District related to the five cultivated plants analyzed.

In subdistricts Baraka and Buntubatu, the decisions made by farmers to maintain plant cultivation were dominated by stable production and the latest amount produced. If these attributes occurred, cocoa production would increase by as much as 300 kg/ha in Baraka, so its utility to farmers would increase by 35 times. Unlike other districts, clove plants in the Malua District are strongly influenced by price stability. The results from the conditional logit model are shown in Table 6, and they show the intention to continue planting certain crops by farmers if there are no changes in the attributes analyzed.

Table 6 - Results of conditional logit analysis for Smallholder intention to continue planting crops, if there are no changes in the attributes analyzed compared to planting cocoa

Subdistrict	Coffee	Clove	Pepper
Alla	0.75	−1.72	−0.02
Anggeraja	2.53	3.44	2.12
Baraka	3.70	2.10	−2.50
Barolo	2.50	2.20	−3.50
Burgin	4.37	5.71	−1.24
Buntubatu	−3.99	−2.56	−7.62
Cendana	-	−4.20	−1.65
Curio	−3.53	−1.03	1.29
Enrekang	−0.15	−4.58	0.07
Maiwa	−3.49	−5.74	−1.78
Malua	−0.18	−0.07	−0.25
Lasalle	0.81	2.83	0.07

The modeling in Table 6 makes alternative plant cocoa an alternative to primary crops for estimating the parameters in the model conditional logs. Based on Table 6, if there are no changes in the attributes of stable production, price, and production, the profitability of growing these plants is reflected in the coefficient associated with the plant. For example, as seen from the coefficient score, farmers would plant coffee as a plant priority for maintenance and selection in the districts of Alla, Baraka, and Bungin, and there would be no changes in the evaluation of quality attributes compared with planting cocoa. In that case, the utility to farmers from planting coffee in subdistricts Alla, Baraka, Baroko, and Bungin is 0.75, 3.7, 2.5, and 4.37 times significant. Meanwhile, in Subdistrict Anggeraja, Bungin, and Masalle, the utility to farmers from planting clove is higher than that of other plants, if there are no changes to the research attributes. Pepper has a higher utility in the districts of Curio and Enrekang if there are no changes to the quality of the variables.

Willingness to pay and crop priority orders

In this research, the percentage preference of farmers to crop a particular crop was rated based on the WTP coefficient. The WTP is the amount that a farmer is willing to pay to maintain a change in the conditioning environment or attribute evaluation. The higher score WTP plant cultivation, the probability of the plant being maintained is higher than tall. Table 7 shows the results of conditional logit modeling of the average WTP score for several plant cultivations. The average WTP was calculated as the ratio of the respective coefficients that were attributed to the price coefficient. Priority plants in each district were sorted based on the WTP percentage, as shown in Table 8.

Table 7 - Average Willingness to Pay (WTP) score associated with changes in attributes

Commodity	Alla		Anggeraja		Baraka		Barolo		Buntubatu		Curio	
	WTP	%	WTP	%	WTP	%	WTP	%	WTP	%	WTP	%
Clove	24876	0.33	20742	0.28	19795	0.26	10054	0.13	20312	0.27	28687	0.24
Pepper	16633	0.30	7769	0.14	12886	0.23	3655	0.07	13300	0.24	13066	0.38
Coffee	8259	0.45	4548	0.25	4695	0.25	4034	0.21	8659	0.25	8486	0.44
Cocoa	9962	0.35	7278	0.27	6243	0.23	4934	0.07	6243	0.23	1868	0.07

Commodity	Bungle		Cendana		Enrekang		Maiwa		Malua		Lasalle	
	WTP	%	WTP	%	WTP	%	WTP	%	WTP	%	WTP	%
Clove	24209	0.32	-	-	25171	0.34	15959	0.29	11654	0.16	57015	0.76
Pepper	17548	0.32	12587	0.23	18122	0.30	25052	0.33	15731	0.29	12984	0.24
Coffee	5659	0.31	-	-	11314	0.43	2722	0.15	6168	0.33	8087	0.44
Cocoa	6221	0.23	6243	0.23	6221	0.23	10017	0.37	12846	0.48	6221	0.23

Note: Conditional logit use method (Krinsky) was employed

Table 8 - Plant priority based on farmers' preferences

District	Priority 1	Priority 2	Priority 3	Priority 4
Alla	Coffee		Cocoa, Clove	Pepper,
Anggeraja	Coffee, Cocoa, and Clove			Pepper
Baraka	Clove	Coffee		Pepper, Cocoa
Barolo	Coffee	Clove		Cocoa, Pepper
Buntubatu	Clove		Coffee	Cocoa, Pepper
Curio	Coffee, Pepper		Clove	Cocoa
Bungle	Coffee, Pepper, and Clove			Cocoa
Cendana	Cocoa, Pepper			
Enrekang	Coffee	Clove	Pepper	Cacao
Maiwa	Cocoa, Pepper	Clove	Coffee	
Malua	Cocoa	Coffee	Pepper	Clove
Lasalle	Clove	Coffee		Cocoa, Pepper

The average WTP was calculated as the ratio of each attribute's coefficient to the price coefficient. The priority of using particular plants in each subdistrict was sorted based on the percentage WTP. For example, in Alla district, based on the percentage of WTP plant cocoa, which has the probability highest for maintenance compared to other plants. Based on the coefficient value, the cocoa WTP in the Alla subdistrict is IDR 12,962. This value shows that the price a farmer would pay to maintain changes in the assessment attributes is IDR 12,969/kg, or 48% of the average cocoa price applied in the study.

In contrast, coffee is the priority three with the lowest percentage of WTP from other plants, namely, 25%. As described earlier, the PAP analysis is an assessment of natural resources andthe environment with an estimated amount of maximum money which wants to issuesomebody to drop the quality environment, so that conclude that the priority of the most prioritized cultivated plants in order is cocoa, cloves/pepper, and coffee. Cloves are a priority crop in other subdistricts (Anggeraja, Baraka, Baroko, Buntubatu, Bungin, and Masalle) based on the evaluation preference of farmers.

Compared to other subdistricts, the WTP values in Barolo subdistrict were lower for all cultivated plants. The calculation of conditional logit using the Krinsky and Robb method shows that the average WTP of the community in the Baroko district is IDR 4034, in the effort to preserve coffee. This means that the community is willing to pay a maximum fee of IDR 4034/kg to contribute to conserving coffee plantations. The Baroko district also had low WTP values. For example, the WTP of clove in this subdistrict was approximately IDR 10,054, or 13% of the average price of clove (IDR 75,000/kg), which indicates that the maximum amount farmers are willing to pay to preserve planting clove if the quality of the environment decreases is IDR 10,054. The low willingness to pay for a decline in the quality of the environment and natural resources in the Baroko district is related to the rampant conversion of land types (particularly plantation land) into plantation horticulture. Based on the WTP value, plant priorities based on the community's preferences in Regency Enrekang could be arranged.

Land suitability

Land attribute membership values

The MF value defines the quality of land attributes and its suitability for growing the analyzed plants. A larger MF value indicates that the land attributes are more suitable for a particular plant, and the values are presented in Figure 7. The MF value is strongly influenced by the control points (b, LCP/UCP, d) and the fuzzy model used in the study. Based on the data processing used here, the thresholds set by researchers are seen to be sensitive, and they affect the MF results of land attributes and the final suitability score. This effect was also reported by Qiu et al. (2014), who found that thresholds cannot be arbitrarily set and must be based on expert knowledge of the situation. The control points used differ depending on the needs of the plants analyzed. Slope and texture apply a correct asymmetric function (the smaller the value, the better the result), and other variables use a left asymmetric function (the more significant the value, the better the result).

Figure 7 - MF values of land attributes

The MF values ranged from 0 to 1, where a value closer to 1 indicates that the land properties are better for plant growth, and a soil attribute with an MF value of 1 indicates that the soil attribute is optimal for plant growth, and vice versa. Based on Figure 7, some soil attributes are seen to be below the tolerance threshold values (<0.4). For example, the MF of pH, CEC, annual temperature, and annual precipitation is less than 0.4 for growing cocoa plants in land unit 2. This shows that the land properties do not meet the requirements for growing cocoa plants in this land unit. In general, the soil attributes for growing coffee plants have higher MF values than those of other plants. In some land units, the individual MF for coffee is equal to 1, which indicates optimal suitability. For example, in land units 3 and 14, land attributes such as temperature, precipitation, and slope provide optimal suitability for coffee growth, with an MF value of more than 0.9.

Land suitability of plantation crops at the research site.

A land suitability assessment involves a multicriteria analysis of a particular land use purpose, and the results depend on the opinions of experts determining the most desirable factor for that purpose.

The land suitability index ranges from 0 to 1, where a value close to 1 indicates optimal suitability. The assessment results in Figure 8 show the pixel values representing moderate suitability (S2) are in the range of 0.6–0.8 and associated with cocoa (0.4–0.86), clove (0.56–0.88), and pepper (0.6–0.91). The optimal class (S1) with an index of 0.62 to 0.92 relates to the suitability of land for growing coffee. From the analysis, only cocoa also belongs to the marginal suitability class (S3). Coffee has a higher land suitability index than other plants, whereas cocoa has the lowest. Figure 9 shows the distribution of land suitability indexes and classes for the plantation crops.

In general, the problems associated with the study area are temperature, CEC, and base saturation, but the most important limiting factors for the growth of coffee plants are pH and base saturation. However, this does not significantly affect the final results of the coffee plant suitability assessment, as pH and base saturation are no more critical than the other soil properties, such as temperature and rainfall. The main limiting factors for cocoa growth are pH, CEC, and temperature. In this land suitability assessment, temperature is essential, and it has the first degree of importance. This agrees with the study of Geo and Saediman (2019), who found that climatic factors strongly influence cocoa growth and that dry months are ideal for its growth. The study area's most crucial limiting factor for clove growth is temperature. According to Ritung et al. (2011), the optimal daily temperature for clove growth is between 26°C and 28°C. Most study areas have an average daily temperature of <26°C; therefore, many locations in the assessment have lower tolerance threshold values for temperature.

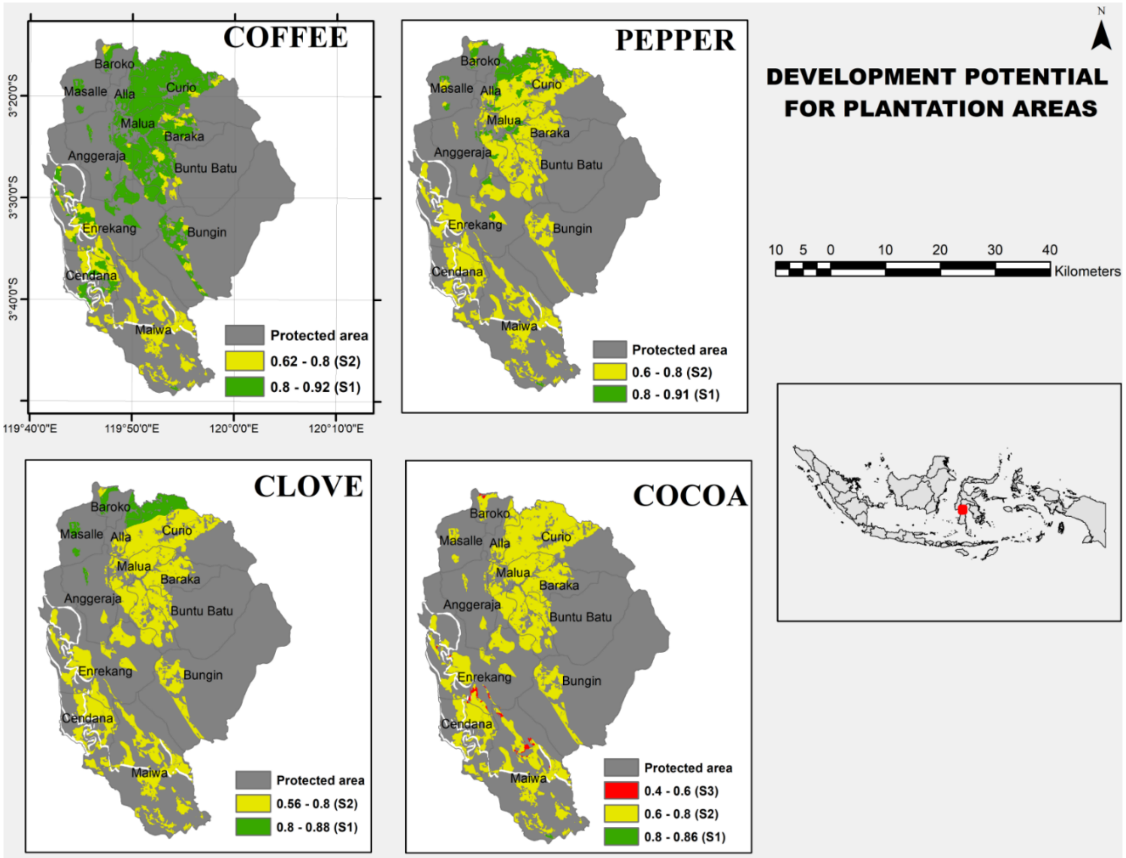

Figure 8 - *Land suitability for planting crops in the research area*

Interrelationship between farmers' preferences and land suitability

Farmers' preferences were compared with the suitability of agricultural land in the study area, to assess the ability of farmers to determine crop priority based on their preferences. A Pearson's correlation analysis provided a significance value of 0.002 (<0.05), suggesting that the prioritization of crops by farmers is influenced by arable land suitability (see Table 9). Table 9 displays the R-value (the symbol for the correlation coefficient value), which is seen to be 0.436 and indicates that land suitability has a moderate impact on farmers' preferences. In Table 9, the R^2 value, or the coefficient of determination (KD), is also shown, and this evidences how well the regression model is formed by the interaction between the independent variable (land suitability) and the dependent variable (plant priority based on farmers' preferences). The KD value obtained was 21%, which can be interpreted as the land suitability variable having a contributory effect of 21% on the farmers' preference variables, and the other 79% being influenced by factors other than land suitability.

Table 9 - Regression model showing relationship between land suitability and farmer preferences

Model	Sum of Squares	df	Mean Square	Model	Unstandardized Coefficients		Standard Coefficient	t	Sig.	R	R Square
					B	Std. Error	Beta				
Regression	1.07	1	1.07	(Constant)	−0.51	0.35		−1.453	0.153	0.436[a]	0.190
Residual	4.55	46	0.10	Domain of LSC	1.42	0.43	0.436	3.287	0.002[b]		
Total	5.62	47									

a. Dependent Variables: Domain of farmer preferences
b. Predictors: (Constant), Domain of LSC

The regression analysis results show that the suitability of agricultural land influences farmers' preferences in determining the type of crop grown. This supports the results obtained when analyzing farmers' preferences, which showed that production stability was one of the most influential factors. Mehrjardi et al. (2020) and Rivera et al. (2019) also found that land suitability influences production results. The positive correlation between land suitability and cultivation priority based on farmers' preferences indicates that conventional farmers do not only consider economical aspects, and their experience and knowledge indirectly means that land suitability is one of factors determining their preferences. Therefore, when developing a strategy to plan a sustainable agricultural area, it is important to recognize the preferences of farmers as economic actors and the ultimate decision-makers.

Conclusions

The land suitability index was higher for coffee than for other plants, and it was associated with optimal suitability, whereas clove, pepper, and cocoa plants were associated with moderate land suitability. Based on the preference analysis, farmers in most of the research areas selected coffee as the top cultivation priority and cocoa as the lowest cultivation priority. The regression analysis results showed that the priority for cultivating plants based on preference had a positive and moderate strength relationship with the suitability of agricultural land. In this respect, 21% of farmers' decisions are influenced by land suitability. A positive correlation between soil suitability and management priority based on farmer preferences indicates that conventional farmers do not only consider economic aspects, and their extensive experience and knowledge indirectly means that soil suitability is one of the factors determining their preferences.

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