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Mapping the Land Suitability Rating of Arabica Coffee Crops: A Geographical Indication Factor-Based Approach

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Authors' contributions

This work was carried out in collaboration among all authors. Author ZC designed the research, wrote the first draft of the manuscript and made spatial decisions from a series of data and map analysis and interpretation. Author NI analyzed and interpreted data and maps, created working maps, and out-1 and out-2 maps. Author Khaerunnisa described and analyzed the physical characteristics and organoleptic properties of coffee beans. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To map land suitability ratings and organoleptic characteristics of arabica coffee using physical and human dimension attributes constructed from geographical indication components.
Study Design: The study was designed in an integrated manner, using a quantitative approach integrated with a qualitative-descriptive approach and supported by field surveys.
Place and Duration of Study: Conducted in 3 sub-districts within the scope of Sinjai Regency, South Sulawesi Province, Indonesia, at altitudes > 800 m.asl., between February 2021 and August 2022.
Methodology: The method for determining the observation location point is on-screen digitization based on the land cover class seen with satellite imagery. Ground truth implementation, 16 location

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points were determined with their respective geographical coordinate positions. To analyze soil properties and characteristics, 41 samples were obtained: An organoleptic test of coffee beans, as many as 3 samples representing the sub-district area.

Results: Mapping using physical dimensions in the West Sinjai area resulted in a moderate land suitability rating with an area of 6,976.46 ha; the Sinjai Borong area obtained a less suitable rating of 7,530.32 ha and a moderate rating of 1,457.17 ha, the Central Sinjai area obtained a less suitable rating of 822.16 ha, and a moderate rating of 1,586.47 ha. The compilation of physical and human dimensions in the West Sinjai area shows a moderate rating of 1,057.97 ha and a suitable rating of 5,918.49 ha, Sinjai Borong produces a moderate rating of 8,821.48 ha and a suitable rating of 166.01 ha, Central Sinjai obtained land suitability with a moderate rating of 986.55 ha and a suitable rating of 1,422.08 ha. West Sinjai and Central Sinjai have an organoleptic score of 88.50, with a more specific floral aroma than Sinjai Borong.

Conclusion: Mapping the land suitability ranking of arabica coffee plants using physical and human dimensions provides clear and logical results.

Keywords: Altitude; arabica coffee; geographical; land suitability; mapping.

1. INTRODUCTION

Land use suitability analysis is essential in sustainable land use and environmental problem solving and is a prerequisite for optimal utilization of available land resources [1,2]. The current evaluation of land suitability in practice is not only land-based or biophysical land but also involves economic and socio-cultural aspects with various complex criteria [3]. In comparison, management aspects need to be identified through survey and mapping activities of land resources and data on climate, soil, and other physical properties of the environment that affect plant growth. The management of land is much influenced by the altitude of the place and geographical position in the order of geographical indication because it determines the performance of the climate, which will affect the dimensions of the natural physical environment, such as soil properties and characteristics, and human dimensions conditions [4] such as social, cultural, and economic which will further determine the suitability of the land and the coffee plant products produced.

Understanding geographical indications about the various dimensions or factors surrounding them is very important for data to be used as a basis for evaluating land suitability ratings [5,6,3]. Organized data collection can provide a structured and systematic understanding of the phenomenon under study [7]. Physiographic factors, such as slope, relief, and elevation, are determined and evaluated using GIS programs [8], further stating that best land management practices can significantly improve productivity and environmental quality.

In today's information age, it is almost only possible for land use plans to be made using geospatial information technology as the primary tool [9]. Geospatial information technology is also proliferating, leading to logical decision-making regarding the suitability of specific land use [10]. With the rapid development of Geographic Information Systems (GIS), with analytical tools that are increasingly reliable and diverse in managing spatial data, the existing land resource evaluation methods can be enriched through the use of analytical methods that can process spatial data of land resources more efficiently and effectively [11]. Furthermore, [7] argues that classification and assessment methods are diverse, ranging from manual techniques with simple tools to geostatistical methods. Spatial modeling with GIS support as part of Multiple Criteria decision-making (MCDM) can determine land's ability, suitability, and availability for specific land use alternatives, including productivity levels and their impact on the performance of other natural resources and the environment.

MCDM is very useful in mapping areas, so this research was conducted to map the land suitability rating and organoleptic properties of Arabica coffee in the West Sinjai, Sinjai Borong, and Central Sinjai Districts within the area of the foot of Mount Bawakaraeng which is at an altitude > 800 m asl, in Sinjai Regency, South Sulawesi Province. It is considered very important to use a GIS approach based on geographical indication (terroir) that involves aspects of the biophysical environment (physical dimension) such as climatic conditions, land morphological forms, physical properties and chemical properties of soil, and non-biophysical factors (human dimension) such as economic and socio-cultural aspects because it is inevitable that the development of future land evaluation models will involve various aspects or dimensions with complex criteria to achieve a logical spatial decision. Indeed, the need for temporal MCDM/A methods under uncertainty emerges as a fundamental research challenge. It is highly expected that this research will contribute to the development of GIS, and the management of data and information generated can help map Arabica coffee land development planning logically and sustainably to increase the income of coffee farmers and surrounding communities while increasing regional income. This also answers the importance of the chosen research location because the existing phenomenon that the higher the area, the lower the income level of farmers can be refuted [12-15].

2. METHODOLOGY

This research was designed in an integrated manner, using a quantitative approach integrated with a qualitative-descriptive approach and supported by field surveys using working maps generated from the interpretation of satellite image data through ArcGIS software with the guided classification method. Risnita et al. [16] Identifying land cover is easy; the method can be done by manually digitizing the screen based on the land cover class seen in satellite imagery using SPOT 6/7 satellite imagery with a 1.5-meter resolution and then correcting it with existing conditions in the field. Overall, this research was designed in 4 major stages, namely: Problem assessment and literature study, Location determination and planning, Field survey, and Analysis, which are described in detail as follows:

2.1 Problem Assessment and Literature Study

This stage suggests a complete research design consisting of planning, map work, ground truth, and analysis, each using its approach or method. In Fig. 1, a diagram of the research design is presented.

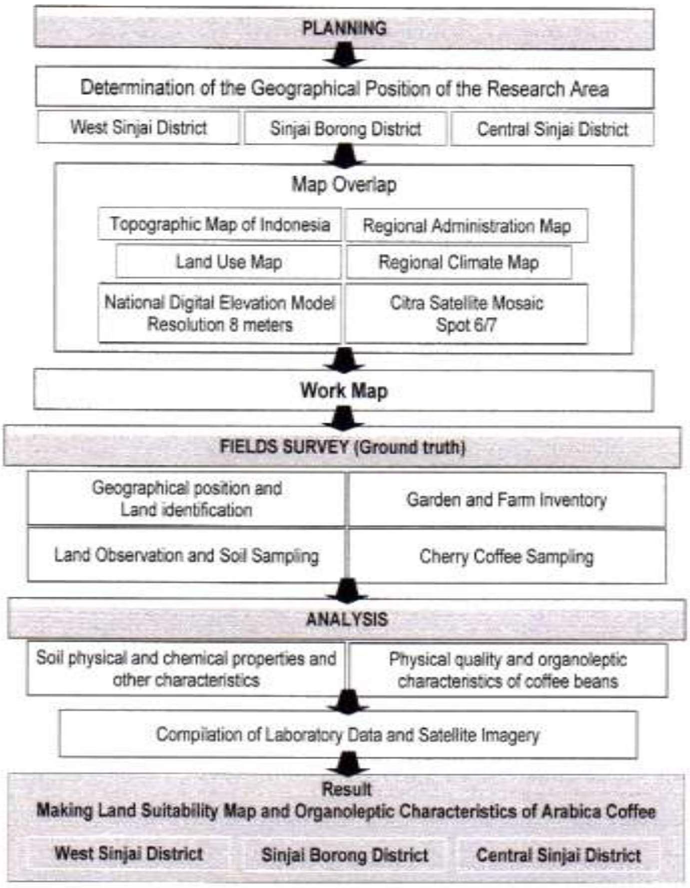

Fig. 1. Diagram of the research design

2.2 Location Determination and Planning

This stage aims to determine the geographical position of the research area by overlaying several maps, including the Indonesian Topographic Map, Regional Administration Map, Land Use Map, Regional Climate Map, 8-meter resolution national digital elevation model, and SPOT 6/7 satellite mosaic image.

The overlapping maps resulted in a working map showing the research location, as presented in Fig. 2, used in field surveys to identify and inventory biophysical and non-biophysical environmental conditions so that data or parameters in geographical indication units can be separated appropriately and correctly. The technical skills required to extract information relevant to land cover dynamics from geospatial data [13].

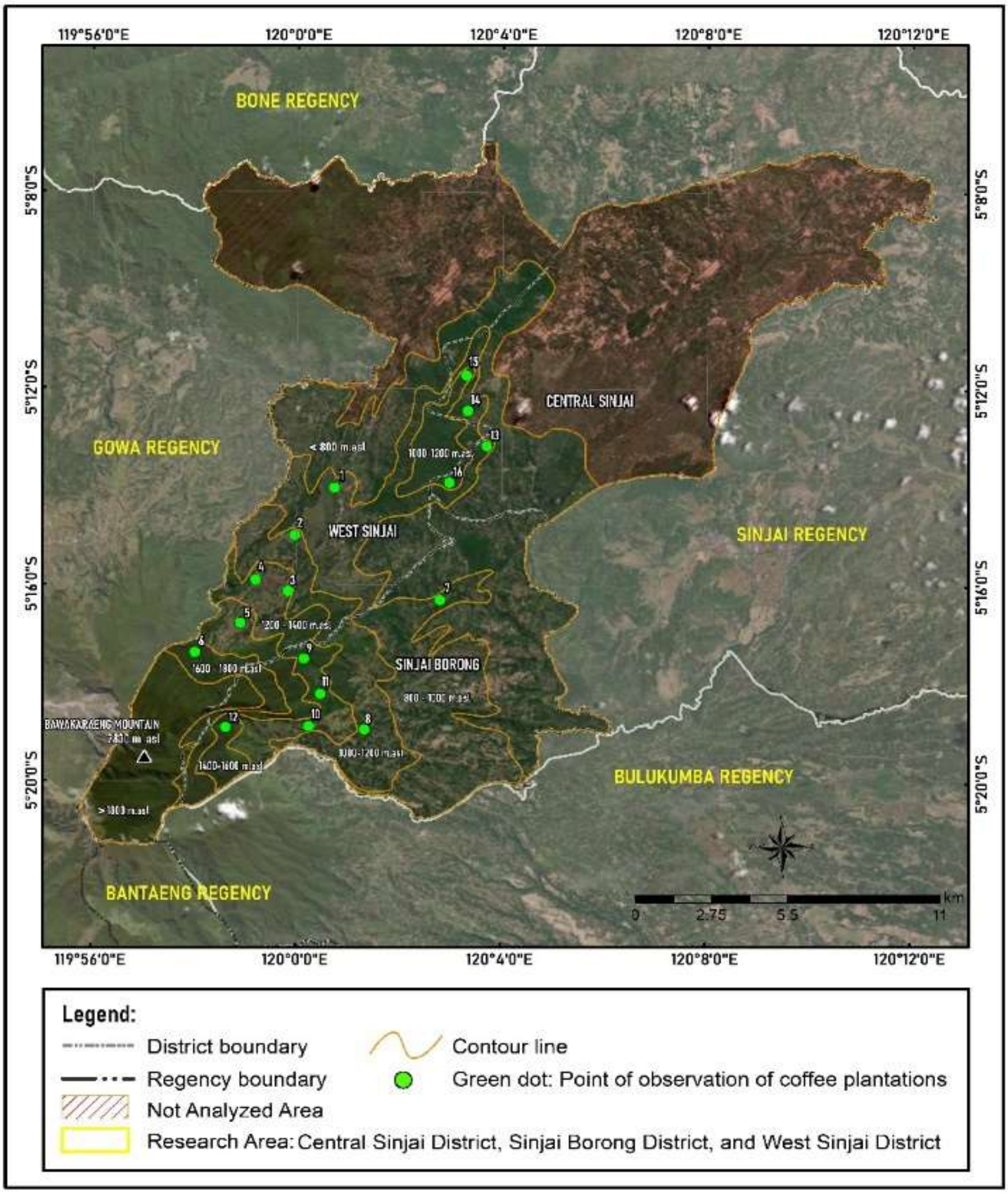

Fig. 2. Location of research area

2.3 Field Survey

The field survey used Global Positioning System (GPS) ground truth to confirm the geographical position of the study area, observation and soil sampling locations, inventory of farms and farmers, and farm locations for cherry coffee sampling. The total area of Sinjai Regency is 87,992.36 ha [14], from the interpretation of the map of the research area, the research area is 18,372.63 ha or 20.88% of the total area of Sinjai Regency.

The location of the observation farms was determined by considering accessibility, size of Arabica coffee farms, and altitude. A total of 16 farm locations were selected based on differences in altitude for observation and soil sampling, namely 6 in West Sinjai Sub-district, 6 in Sinjai Borong Sub-district, and 4 in Central Sinjai Sub-district. Meanwhile, three farm locations representing each sub-district were taken for coffee cherry fruit samples.

Observations of land conditions and soil sampling were done by making cross-sectional profiles, recording geographical position, altitude, slope, and physiography, and then observing morphological forms and land conditions. Components of the biophysical environment of the land with the main abiotic factors, including soil and rooting depth, horizon/layer boundaries, and unique signs present, followed by taking soil samples at each horizon/layer for laboratory analysis needs; this component is described as a geographical indication included in the attributes of the physical dimension component. Meanwhile, farm and farmer inventories are included in the biophysical component of land, with the main factors being coffee land area, cherry production, land maintenance efforts, crop maintenance, fruit picking, and post-harvest measures. Meanwhile, the non-biophysical component of land's main factors are economic factors, socio-culture, policies and norms, road accessibility from farms to economic growth centers, local wisdom, farming community preferences, and farmer institutions. These components are translated into geographical indications that include attributes of the human dimension component, namely the relationship between humans and land.

Sampling of cherry coffee fruit at farm locations was conducted after farm and farmer inventory activities were completed at peak harvest time. Representative farms were farms that had common conditions throughout the subdistrict.

2.4 Analysis

The analysis stage consists of analyzing the physical and chemical properties of soil, analyzing the physical quality and organoleptic characteristics of coffee beans, and using the following analysis techniques

2.4.1 Analysis of soil physical and chemical properties

The soil's physical and chemical properties were analyzed in the soil physics and chemistry laboratory, Department of Soil Science, Faculty of Agriculture, Hasanuddin University. Parameters and methods of analysis are presented in Table 1.

Table 1. Methods for Analyzing Soil Physical and Chemical Parameters

Parameter	Method of analysis
Soil texture	Hydrometer
Bulk density	Gravimetric
C-organic	Walkey and Black
Cation exchange capacity (CEC)	NH_4OAc pH 7.0
Base saturation (BS)	Extraction NH_4OAc

2.4.2 Analysis of physical quality and organoleptic characteristics of coffee beans

Analysis of physical quality and organoleptic characteristics of coffee beans such as Fragrance/aroma, Flavor, Aftertaste, Acidity, Body, Uniformity, Balance, Clean cup, Sweetness, and Overall using the cupping test method conducted at the testing laboratory, the Indonesian Coffee and Cocoa Research Center. The characteristics and methods of testing the physical quality of coffee beans are presented in Table 2.

2.4.3 Analysis technique

Structurally, the analysis technique follows the following steps: i). Determination of criteria (attributes) in geographically indicated spatial components, consisting of physical and human dimension components. ii). Selected attributes that performed well or were significant to achieving the research objectives. iii). All selected attributes were built assuming positive statements related to the output of land suitability ratings, then calculations and determination of scores by standardizing attribute scales and weighting were carried out manually using a Likert scale [15-17]. The attributes of the components of the positive assumption statement of the physical and human dimensions are presented in Table 3. At the same time, the scale or weight relationship with the assessment statement is presented in Table 4.

Table 2. Characteristics and methods of analyzing the physical quality of coffee beans

Characteristic physic	Method of analysis
Life insect	SNI 01-2907-2008; 7.1
Rotted/Mouldy	SNI 01-2907-2008; 7.2
Moisture content	SNI 01-2907-2008; 7.3
Foreign matters	SNI 01-2907-2008; 7.4.2
Large size, retained on Sieve No.16	SNI 01-2907-2008; 7.4.1
Medium size, passed Sieve No.16, retained Sieve No.15	
Small size, passed Sieve No.15, retained on Sieve No.13	
Defect number	SNI 01-2907-2008; 7.4.2

Table 3. Attributes of the components of the physical dimension and human dimension assumption positive statements

Number	Component	Selected attribute	Assumption statement
1	Physical dimension	Soil depth	The deeper the soil solum of the land, the more suitable it is for Arabica coffee plants.
2		Rooting depth	The deeper the root zone of the land, the more suitable it is for Arabica coffee plants.
3		Slope	The smaller the slope of the land, the more suitable it is for Arabica coffee plants.
4		Rock on the surface	The fewer rocks on the surface of a field, the more suitable it is for Arabica coffee plants.
5		Clay fraction content	The more clay fraction content in a land, the more suitable it is for Arabica coffee plants.
6		Bulk density	The smaller the soil bulk density of land, the more suitable it is for Arabica coffee plants.
7		C-organic soil	The higher the C-organic content of land, the more suitable it is for the growth of Arabica coffee plants.
8		Cation exchange capacity (CEC)	The higher the CEC of land, the more suitable it is for Arabica coffee plants.
9		Exchangeable base	The higher the sum of exchangeable bases in a land, the more suitable it is for Arabica coffee plants.
10		Base saturation	The higher the base saturation value of land, the more suitable it is for Arabica coffee plants.
11	Human dimension	The expanse of land	The wider the expanse of land, the more suitable it is for Arabica coffee plants.
12		Production of coffee cherry	The higher the production of coffee cherry in a field, the more suitable it is for Arabica coffee plants.
13		Land management	The better the land management, the more suitable it is for Arabica coffee plants.
14		Plant maintenance	The better the maintenance of plants in a land, the more suitable it is for Arabica coffee plants.
15		Harvest coffee cherry	The better the procedure for harvesting coffee cherry in a field, the more suitable it is for Arabica coffee plants.
16		Post-harvest processing	The better the post-harvest processing of an area, the more suitable it is for Arabica coffee plants.

Number	Component	Selected attribute	Assumption statement
17		Garden accessibility	The closer the accessibility of the garden to the center of economic growth, the more suitable it is for Arabica coffee plants.
18		Local wisdom	The better the implementation of local wisdom in an area, the more suitable it is for Arabica coffee plants.
19		Community preference	The better the preferences of the community of a region, the more suitable it is for Arabica coffee plants.
20		Farmer group institutions	The stronger the farmer group institutions, the more suitable for Arabica coffee plants.
21		Local regulation	The more precise the status of regional regulations in an area, the more suitable it is for Arabica coffee plants.
22		operational standard	The more precise the implementation of operational standards from upstream to downstream in an area, the more suitable it is for Arabica coffee plants.

Table 4. Relationship between scale/score and rating of land suitability statement

Scale/Score	Rating	Land suitability statement rating
$\geq$ 4.51	5	Very Suitable
3.51 – 4.50	4	Suitable
2.51 – 3.50	3	Moderat
1.51 – 2.50	2	Less Suitable
$\leq$ 1.50	1	Not Suitable

A series of stages of calculation, analysis, and interpretation produces an output-1 map that considers the components of the physical dimension, and output-2 considers the physical and human dimensions. This is intended to determine the extent of the role of the human dimension in determining the land suitability rating. Decision-making on the suitability of a public investment project has traditionally been based on its economic feasibility study, and this has been complemented by a more holistic vision of reality in which social and environmental aspects are explicitly considered alongside economic factors [18].

3. RESULTS AND DISCUSSION

Climatic conditions and altitude need to be described to get a specific location picture related to the level of land suitability of Arabica coffee plants and the performance characteristics of Arabica coffee beans [3].

The results of calculating climatic conditions such as rainfall, temperature, and humidity in the study area based on rainfall data [19] and [20] from 2010 - 2020 ranged from 1,915 – 4,663 mm/year with an average of 2,609 mm/year. Based on the Schmidt-Fergusson climate classification system, the study area is classified as climate type A, a rainy tropical climate with a Q Gradient value of 0% because all months are included in the wet month, which is >100mm/month. The average monthly temperature is more than 18 degrees Celsius, and the annual temperature in the West Sinjai area is about 15 C, in Sinjai Borong about 20 C, and in Central Sinjai about 23 °C. The rainfall pattern in Sinjai Regency is a local rainfall pattern, which is more influenced by the local conditions of an area by orographic effects and has one maximum peak that occurs around the middle of the year, namely in June [21]. Sys et al. [22] explained that Arabica coffee plants can produce and are classified according to rainfall ranging from 800 – 2,500 mm/year with optimum rainfall between 1,400 – 1,600 mm/year, the optimum average temperature of 15 – 24 °C, and relative humidity of 55 – 90%. Therefore, regarding the climatic conditions, the research location is classified as suitable for Arabica coffee plants.

Climatic factors and altitude of place are condition factors that affect state variables, such as the attributes of physical dimension components and human dimension components. The altitude of the place as an inhibiting factor to the resistance variables of the physical dimension and human dimension attributes shows differences, both for each observation point and between sub-districts. Table 5 presents the geographical position and land morphology of each soil profile.

The results of identification and observation on 16 soil profiles, in addition to recording the geographical position, also made observations of the morphological shape of the soil, followed by taking soil samples in each soil layer/horizon. 41 samples were taken to be analyzed for soil physical and chemical properties. The results of the analysis used as attributes are presented in Table 6.

The calculations result, and analysis based on the attributes of the physical dimension components (numbers 1 to 10 in Table 3) resulted in an output-1 map, showing a land suitability area with a less suitable rating of 8,352.48 ha and a moderate rating of 10,020.10 ha. The mapping results are presented in Fig. 3.

Based on the attributes of the physical and human dimension components (numbers 1 to 22 in Table 3), the map-2 output shows the area of land suitability with a moderate rating of 10,866.00 ha, a suitability rating of 7,506.58 ha, and a less suitability rating of none, presented in Fig. 4.

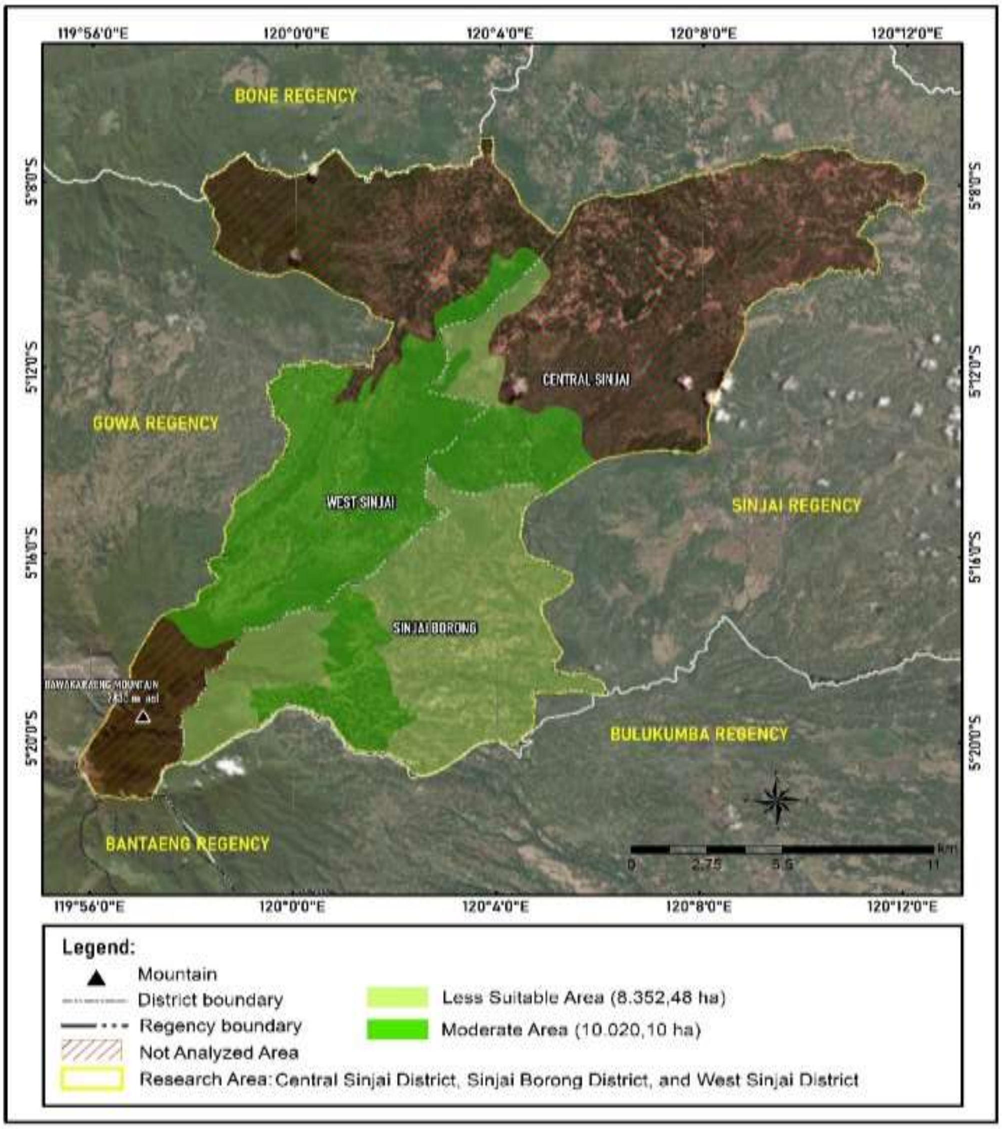

Fig. 3. Results mapping the rating of land suitability based on the components of the physical dimension

Table 5. Geographical position and morphological forms of land in each soil profile

Profil number	Coordinate Decimal Degree		Altitude (m.asl)	Slope (%)	Soil depth (cm)	Rooting depth (cm)
	x	y				
1	120,0121482308	-5,2337426226	805	25	100	50
2	119,9992473740	-5,2498681218	1,050	43	200	118
3	119,9970925391	-5,2687145105	1,216	43	68	40
4	119,9864497609	-5,2649481260	1,300	35	137	60
5	119,9816680813	-5,2796393467	1,500	40	65	65
6	119,9668589451	-5,2895269169	1,600	43	118	60
7	120,0466256663	-5,2716182148	901	47	70	20
8	120,0221353279	-5,3156368433	1,114	29	50	17
9	120,0023705246	-5,2916788249	1,231	30	75	50
10	120,0040301988	-5,3146005828	1,239	30	64	50
11	120,0077447247	-5,3036384676	1,245	52	66	59
12	119,9840120014	-5,3192312047	1,415	29	71	49
13	120,0616340837	-5,2194607021	800	30	120	20
14	120,0564532847	-5,1905327197	935	40	75	22
15	120,0533487453	-5,2083979634	1,035	26	70	32
16	120,0480307117	-5,2343718590	1,078	60	100	32

Table 6. Results of the analysis of some of the soil properties used as attributes

Profil number	Profil notation	Soil Depth (cm)	Clay fraction (%)	Bulk density (g/cm3)	C-organic (%)	Cation exchange capacity (cmol/kg soil)	Exchangeable base (cmol/kg soil)	Base saturation (%)
1	01.01.1	0 - 9	51	0.74	2.96	27.38	8	29.22
	02.01.2	9 - 21	28	0.98	2.30	22.36	14	62.61
	03.01.3	21 - 78	58	-	1.89	16.62	8	48.13
	04.01.4	78 – 100	84	-	0.47	12.75	7	54.90
2	05.02.1	0 - 31	69	1.04	1.91	26.96	11	40.80
	06.02.2	31 - 70	59	0.90	1.26	23.51	8	34.03
	07.02.3	70 – 200	80	-	0.56	22.36	6	26.83
3	08.03.1	0 - 25	58	1.08	2.44	31.35	6	19.14
	09.03.2	25 - 68	73	0.86	1.72	29.26	6	20.51
4	10.04.1	0 - 36	32	0.66	2.76	21.84	9	41.21
	11.04.2	36 - 48	41	0.74	2.43	21.21	8	37.72
	12.04.3	48 - 114	46	-	1.71	22.47	7	31.15
	13.04.4	114 - 34	43	-	0.41	21.23	7	32.97
5	14.05.1	0 - 10	42	0.63	2.91	34.90	8	22.92
	15.05.2	10 - 28	38	0.89	2.81	19.02	7	36.80
	16.05.3	28 - 65	56	-	1.51	22.99	8	34.80
6	17.06.1	0 - 11	23	0.56	2.24	22.36	8	35.78
	18.06.2	11 - 25	62	0.60	1.54	28.63	10	34.93
	19.06.3	25 - 70	56	-	1.41	26.96	8	29.67
7	20.07.1	0 - 25	39	1.34	1.70	28.32	8	28.25
	21.07.2	25 - 75	36	1.31	1.14	24.45	10	40.90
8	22.08.1	0 - 19	81	0.95	2.91	28.63	6	20.96
	23.08.2	19 - 50	64	1.42	1.52	19.54	7	35.82
9	24.09.1	0 - 25	57	1.01	2.26	26.75	7	26.17
	25.09.2	25 - 45	51	1.15	1.26	23.62	6	25.40
10	26.10.1	0 - 23	43	0.78	2.68	33.65	10	29.72
	27.10.2	23 - 64	64	0.90	1.90	34.38	10	29.09
11	28.11.1	0 - 16	57	0.84	1.70	29.78	7	23.51
	29.11.2	16 - 66	63	1.00	0.87	28.84	7	24.27
12	30.12.1	0 - 29	56	1.07	2.92	21.32	6	28.14

Profil number	Profil notation	Soil Depth (cm)	Clay fraction (%)	Bulk density (g/cm3)	C-organic (%)	Cation exchange capacity (cmol/kg soil)	Exchangeable base (cmol/kg soil)	Base saturation (%)
	31.12.2	29 - 71	51	1.01	1.65	17.35	7	40.35
13	32.13.1	0 - 32	41	1.04	1.58	29.57	9	30.44
	33.13.2	32 - 56	51	1.32	1.31	26.02	9	34.59
	34.13.3	56 - 120	36	-	0.48	28.63	6	20.96
14	35.14.1	0 - 18	37	1.09	1.70	21.84	8	36.63
	36.14.2	18 - 40	39	1.25	1.92	21.11	6	28.42
	37.14.3	40 - 75	43	-	1.01	19.96	7	35.07
15	38.15.1	0 - 20	51	1.00	2.77	26.23	9	34.31
	39.15.2	20 - 48	50	1.02	2.04	25.71	8	31.12
16	40.16.1	0 - 29	55	1.03	2.83	32.81	11	33.53
	41.16.2	29 - 84	47	1.13	1.53	29.26	10	34.18

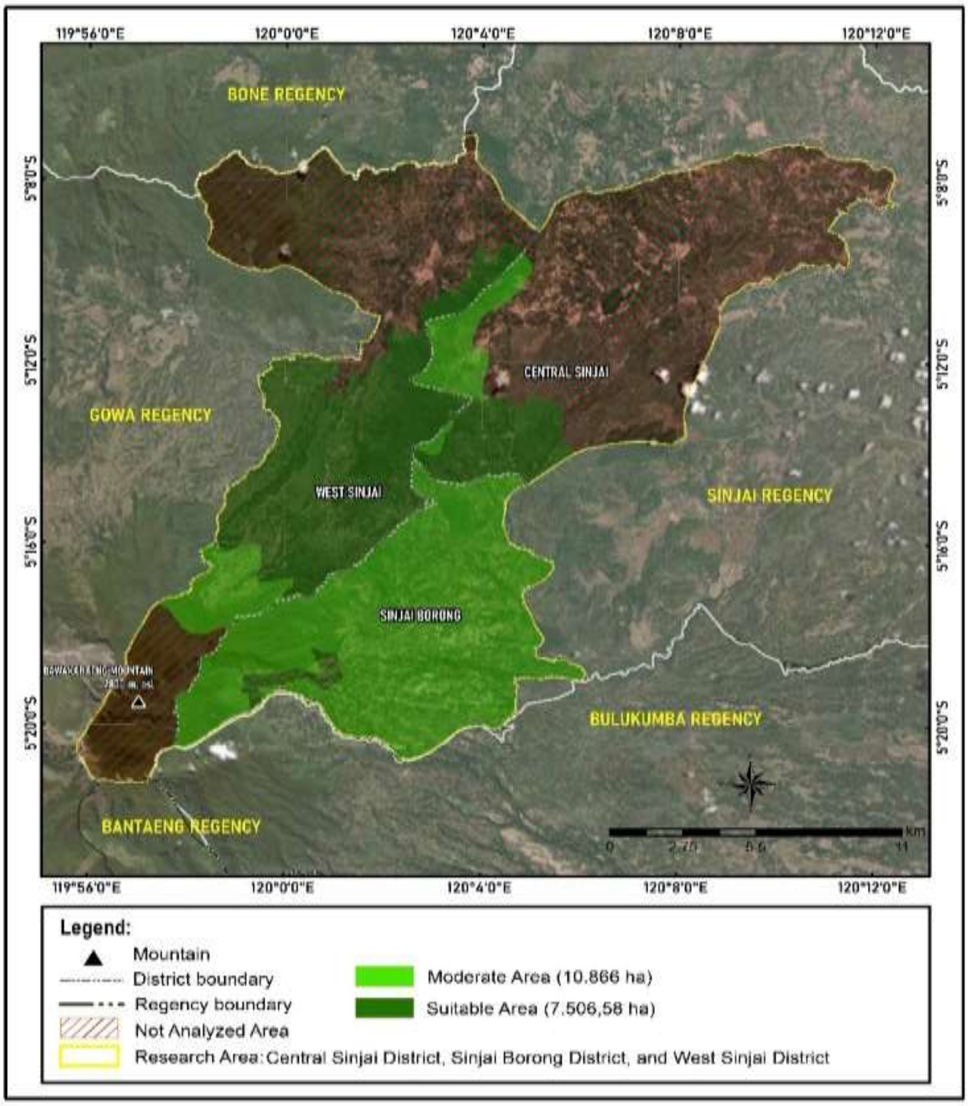

Fig. 4. Mapping results of land suitability rating based on the components of the physical dimension and human dimension

Changes in the land suitability rating with the addition of the human dimension component can significantly increase the land suitability rating by 1 point. As shown in Fig. 3, the area with a less suitable rating was found to be 8,352.48 ha, while in Fig. 4, the less suitable rating was no longer found; even an area with a suitable rating of 7,506.58 ha was found.

The GIS approach is very good and precise in determining the land suitability rating of Arabica coffee plants from the component attributes of physical dimension and human dimension. One of the advantages of this integration is that decision-makers can introduce an assessment of a GIS-based decision [23,24]. The results of calculating the score value obtained from the standardization of the attribute scale, which also shows the profile number, district area, altitude, and land area in detail, are presented in Table 7.

Looking at the results of the land suitability ranking assessment (in Table 7), in the West Sinjai area at an altitude of 1,300 - 1,600 m.a.s.l., there was no change in the land suitability ranking (from output-1 to output-2). This means that the human dimension component has no effect, as well as in the Central Sinjai area at an altitude of 1,035 - 1,078 m.asl. However, in contrast to the Sinjai Borong area, the altitude of the place significantly influences the assessment results of its land suitability rating, except at an altitude of 1,114 m.asl.

Table 7. The results of the calculation of the score obtained from standardized attribute scales

Profile Number	District area	Altitude m.asl	Land area ha	Output-1		Output-2	
				Score	Suitability rating	Score	Suitability rating
1	West Sinjai	805	4,733.33	3.31	Moderate	3.89	Suitable
2		1,050	770.16	3.31	Moderate	3.89	Suitable
3		1,216	415.00	2.88	Moderate	3.54	Suitable
4		1,300	277.81	2.88	Moderate	3.43	Moderate
5		1,500	397.76	2.75	Moderate	3.21	Moderate
6		1,600	382.40	2.88	Moderate	3.18	Moderate
7	Sinjai Borong	901	5,833.61	2.19	Less suitable	3.14	Moderate
8		1,114	1,291.16	2.63	Moderate	3.39	Moderate
9		1,231	223.73	2.38	Less suitable	3.11	Moderate
10		1,239	166.01	3.44	Moderate	3.71	Suitable
11		1,245	373.89	2.25	Less suitable	3.04	Moderate
12		1,415	1,099.09	2.50	Less suitable	3.11	Moderate
13	Central Sinjai	800	1,422.08	2.63	Moderate	3.54	Suitable
14		935	822.16	2.19	Less suitable	3.29	Moderate
15		1,035	90.54	2.88	Moderate	3.46	Moderate
16		1,078	73.85	2.94	Moderate	3.50	Moderate

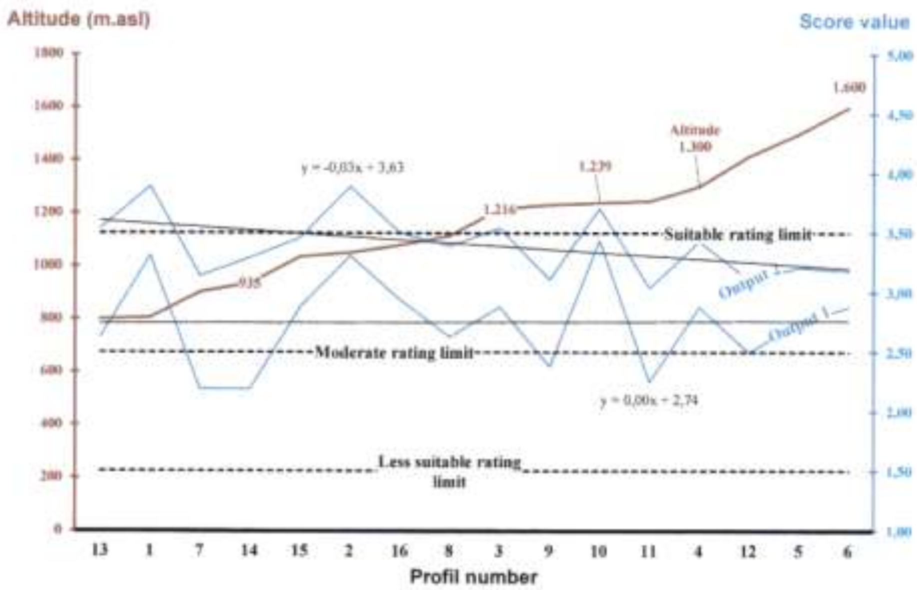

Fig. 5. The relationship between the altitude of the place with the score results from output-1 and output-2

Overall, altitude as a state factor through climate factors can only influence the land suitability rating assessment [25] of the performance of the human dimension component. Each state factor variable used as an attribute (numbers 11 to 24 in Table 3) has performance and simultaneously affects the land suitability rating assessment results for Arabica coffee plants in the study area. Some study area physiographic factors include slope, aspect, relief, and mean elevation. To further see this phenomenon, the relationship between elevation and the overall rating (score) in the study area generated from output-1 and output-2 is presented in Fig. 5.

Output-1 from calculating the physical dimension attribute when associated with altitude shows the regression equation $y = 0.00x + 2.74$; this indicates that the overall altitude is not directly correlated with the final score. The score difference is because each physical dimension attribute (numbers 1 to 10 in Table 3) performs differently towards the final score. Whereas output-2 from calculating all physical dimension and human dimension attributes when connected to altitude shows the regression equation $y = -0.03x + 3.63$; overall altitude negatively correlates with the final score.

The difference in the relative score values between output-1 and output-2, as shown in Fig. 5, shows different distances at each altitude. It can be seen that at an altitude of 935 m.asl, it has a greater distance than other altitudes, while the distance is the smallest at an altitude of 1.239 m.asl. The performance of the human dimension attribute can be optimal at an altitude of +1,000 m.asl. [26] stated that there is a real correlation between the altitude of the place and several soil chemical properties and coffee production.

The results of testing each sub-district's physical quality and organoleptic characteristics are presented in Table 8 and Table 9, giving a specific description. From the results of this test, it can be stated that within the scope of the research area, the essential characteristics of coffee beans are the physical quality of coffee beans classified as quality 1 with large bean sizes and classified as specialty grade and organoleptic characteristics, fragrance/aroma, flavor, uniformity, clean cup, sweetness, and overall, as well as flowery and honeyed flavors because they have the same characteristics in each sub-district area. Shade affects the taste of Arabica coffee at all altitudes, namely on the quality of flavor, body, quality aftertaste, and balance; the taste of Arabica coffee in shaded conditions has a higher rating scale, with a total taste score of 83.75 compared to 82.50 for unshaded coffee [2]. However, if sorted based on the final score from the results of the characteristic organoleptic test, it can be written West Sinjai > Central Sinjai > Sinjai Borong.

Table 8. Taste test results from organoleptic characteristics

Number	Characteristic organoleptic	Cup testing Score West Sinjai	 Sinjai Borong	 Central Sinjai
1	Fragrance/aroma	8.50	8.50	8.50
2	Flavor	8.50	8.50	8.50
3	Aftertaste	8.50	8.00	8.50
4	Acidity	7.75	8.00	8.00
5	Body	8.25	7.75	8.00
6	Uniformity	10.00	10.00	10.00
7	Balance	8.50	8.00	8.50
8	Clean cup	10.00	10.00	10.00
9	Sweetness	10.00	10.00	10.00
10	Overall	8.50	8.50	8.50
Final Score		88.50	87.25	88.50
Notation		Specialty Grade	Specialty Grade	Specialty Grade
Comment		Sweet Corn Aroma, Flowery, Honeyed, Excellent	Sweet Corn Aroma, Flowery, Honeyed	Brown sugar, Honeyed, Spicy, Flowery

Table 9. Results of the physical quality test of coffee beans

Characteristic physic	Result of analysis
Life insect	Absent
Rotted/Mouldy	Absent
Moisture content	11.8%
Foreign matters	0%
Large size, retained on Sieve No.16	0%
Medium size, passed Sieve No.16, retained Sieve No.15	
Small size, passed Sieve No.15, retained on Sieve No.13	
Defect number	0.1%
Conclusion	Quality 1 Large beans size

4. CONCLUSION

A simple GIS approach using calculations based on a Likert scale in mapping the land suitability rating of Arabica coffee plants based on geographical indications can be separated from those that use physical dimension attributes as output-1, with those that use physical dimension and human dimension attributes as output-2.

The results of the mapping in the West Sinjai region, output-1 obtained a moderate land suitability rating for the entire study area, namely an area of 6,976.46 ha, while output-2 a moderate land suitability rating of 1,057.97 ha., and a suitable rating of 5,918.49 ha. This indicates that the human dimension has a performance in increasing the land suitability rating, but the performance of the human dimension attribute is only optimal at altitudes <1,200 m.asl. The mapping results in the Sinjai Borong area, output-1 obtained land suitability with a less suitable rating of 7,530.32 ha and a moderate rating of 1,457.17 ha, while output-2 obtained land suitability with a moderate rating of 8,821.48 ha and a suitable rating of 166.01 ha. This indicates that the human dimension performs well in increasing the land suitability rating, except at an altitude of 1,114 m.asl. The mapping results in the Central Sinjai region, output-1 obtained land suitability with a less suitable rating of 822.16 ha and a moderate rating of 1,586.47 ha, while output-2 land suitability with a moderate rating of 986.55 ha and a suitable rating of 1,422.08 ha. This indicates that the human dimension performs reasonably well in increasing the land suitability rating, except at altitudes >1,035 m.asl. When looking at the altitude resistance factor through the resistance variable from the human dimension, it can be concluded that the human dimension has good or optimal performance at altitudes <1,200 m.asl. Meanwhile, regarding the quality of coffee beans from each sub-district, West Sinjai is better than Central Sinjai and Sinjai Borong, and Central Sinjai is better than Sinjai Borong.

Overall, using simple GIS with calculations based on a Likert scale in mapping land suitability ratings using physical and human dimension attributes provides clear and logical results and can separately provide an overview of the performance of each attribute used.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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