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Land Suitability Evaluation and Potential Land Development for Arabica Coffee in Geumpang Subdistrict, Aceh Province, Indonesia

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Abstract

Aceh Province is the leading producer of Arabica coffee in Indonesia, contributing 32.3% of the total national product. Despite the growing demand for coffee, there has been a noted decline in domestic production. To address this issue and enhance coffee production, it is essential to identify and develop new cultivation areas that adhere to established suitability criteria based on comprehensive land suitability assessments. The Geumpang Subdistrict, situated on the slopes of the Peut Sagoe Mountains at an elevation exceeding 1,000 m asl., presents over 1,000 ha of land that is potentially suitable for cultivation. The primary objective of this research is to evaluate the land suitability for Arabica coffee cultivation within this subdistrict. A descriptive method combined with field surveys was employed to collect relevant data, including soil samples, slope gradients, and physical soil properties. Soil analyses were conducted at the Soil and Plant Analysis Laboratory, Faculty of Agriculture, Universitas Syiah Kuala. For the assessment of land characteristics, Land Map Units (SPL: *Satuan Peta Lahan*) were developed using Geographic Information System (GIS) tools, specifically ArcGIS software. The findings of this study reveal that the Geumpang Subdistrict experiences high annual rainfall, exceeding 3,000 mm/year, with less than one month of dry conditions. Based on the evaluation of both physical and chemical soil properties, the land has been categorized into unsuitability classes N. Therefore, the cultivation of Arabica coffee in this region is deemed feasible, contingent upon the implementation of appropriate agronomic management practices.

Keyword: Coffee, geospatial, GIS analysis, sustainable agriculture

INTRODUCTION

Coffee is a vital plantations commodity for Indonesia, ranking just after palm oil, rubber, cocoa, and coconut. It plays a crucial role in the livelihoods of approximately 7.8 million farmers (Ditjenbun, 2024). In 2022, Indonesia's coffee plantations covered a total area of 1,265,930 hectares, yielding an impressive 774,961 tons of coffee (BPS, 2023). Notably, Robusta coffee constitutes 73% of this production, while Arabica coffee makes up 27% (BPS, 2023). This impressive output positions Indonesia as the fourth-largest coffee producer globally, following Brazil, Vietnam, and Colombia. In the same year, Indonesia exported 437,555 tons of coffee, generating a trade value of USD 1,148,383 (BPS, 2023). Aceh Province stands out as the leading producer of Arabica coffee in the country, contributing 32.3% of the total production, with North Sumatra closely behind at 31.98% (Ditjenbun, 2023). Almost all Arabica

coffee in Aceh is cultivated in the Gayo Highlands, which include Aceh Tengah Regency, Bener Meriah Regency, and Gayo Lues Regency, as well as parts of North Aceh and Pidie. In 2020, the total area of Arabica coffee plantations in Aceh was 103,495 ha (Ditjenbun, 2024). To increase coffee production to meet market demand, two key strategies can be implemented: intensification, which focuses on improving productivity, and extensification, which involves expanding into new areas.

Pucok Village, located in the Geumpang Subdistrict of Pidie Regency, Aceh Province, has excellent potential to become a new area for growing Arabica coffee. This region is commonly referred to as the Transmigration Zone SP III and SP V, where coffee cultivation was initially promoted by the Transmigration Department—previously known as the Department of Transmigration and Forest Settler Resettlement—around 1995, prior to the Aceh conflict (Vania, 2021). However, no recent data is available regarding land suitability or the outcomes of this initiative. The site meets all the basic requirements to develop Arabica coffee production in Aceh. It encompasses over 1,000 hectares on the slopes of the Peut Sagoe Mountains, situated at an elevation above 1,000 m asl. Additionally, the average temperature and rainfall in this area are ideal for cultivating Arabica coffee.

Land evaluation is a systematic process that estimates the suitability and potential of land for various applications, encompassing both agricultural and non-agricultural uses. The suitability of a region's land for specific agricultural development is fundamentally determined by the alignment of the physical characteristics of the environment. These characteristics include climate, slope, relief, surface and subsurface rock formations, rock outcrops, hydrology, and the growth requirements of crops (Djaenudin *et al*., 2000). Furthermore, land suitability evaluation can be viewed as an assessment of the land's potential for diverse agricultural systems in general, without focusing on specific crop types (Auliansyah *et al.*, 2019). According to the Food and Agriculture Organization (FAO) (1976), several soil qualities significantly influence crop yield and production. These factors include nutrient availability, oxygen levels in the root zone, the medium for root development, salinity, toxicity, flooding intensity, climate, moisture levels, the characteristics of crop varieties, and the impact of pests and diseases.

In Indonesia, Arabica coffee thrives at elevations of over 1,000 m asl., requiring annual rainfall between 1,250 and 2,500 mm, as well as a minimum of 1 to 3 dry months (Permentan, 2014; Baon, 2016). Optimal growth conditions for Arabica coffee include land with a slope of less than 30% and an effective soil depth greater than 100 cm, which is essential for robust root development. Conversely, Robusta and Liberica coffee varieties perform best at elevations ranging from 100 to 600 m asl., also necessitating annual rainfall of 1,250 to 2,500 mm, but requiring a minimum of 3 dry months (Permentan, 2014). This study seeks to evaluate the suitability of land in the Geumpang Subdistrict of Aceh for the cultivation of Arabica coffee, addressing the current lack of information on this topic. The results and observational data derived from this research will provide a valuable reference for local governments as they formulate policies to promote Arabica coffee development in Aceh Province, Indonesia.

MATERIALS AND METHODS

This study was conducted in the Geumpang Subdistrict of Pidie Regency, as illustrated in Figure 1. Soil analysis was carried out at the Soil and Plant Analysis Laboratory, Faculty of Agriculture, Universitas Syiah Kuala. The laboratory offers testing services through

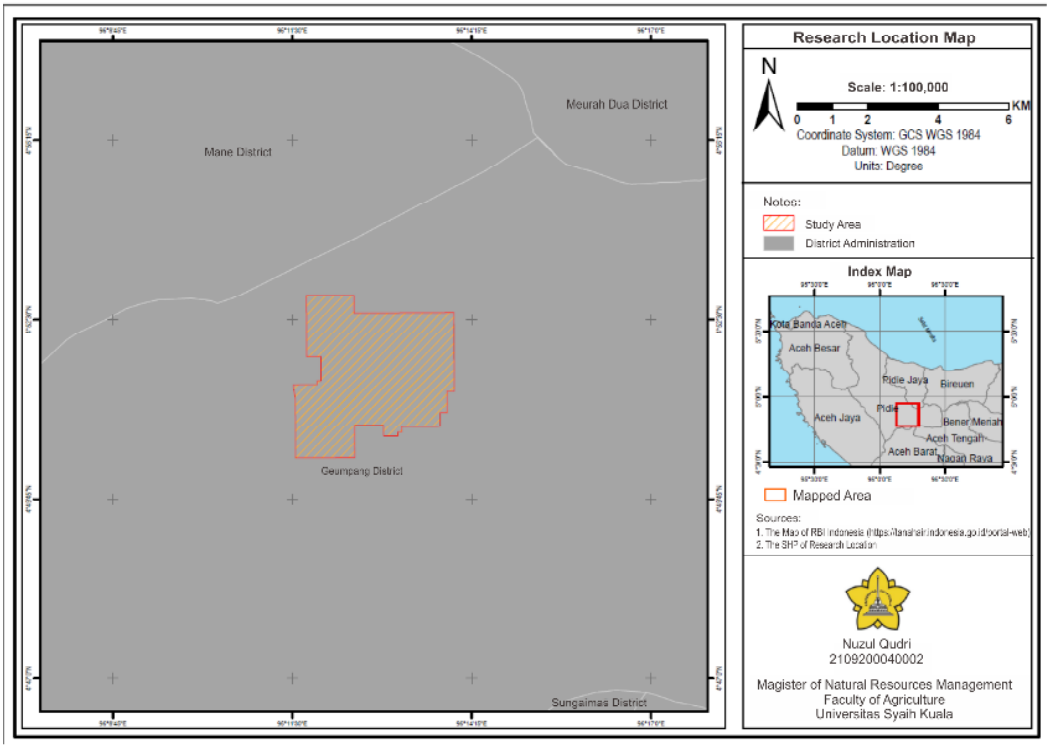

Figure 1. Research location map in Geumpang Subdistrict, Aceh, Indonesia

the Syiah Kuala University Integrated Laboratory Technical Implementation Unit. It has received certification from the Indonesian National Accreditation Committee, identified by the number LP-1333-IDN. Additionally, image analysis was performed at the Remote Sensing and Cartography Laboratory at the same institution. The research took place from July to October 2024. The methodology employed descriptive and survey techniques, followed by comparative analysis. This involved assessing the land characteristics measured both in the field and in the laboratory against the established criteria for Arabica coffee land suitability classes, which are compiled based on the specific requirements for crop production and growth, as outlined in Permentan (2014).

To collect land characteristics from a designated land unit, a Land Map Unit (SPL: *Satuan Peta Lahan*) was established as a working map (Figure 2). This SPL was constructed utilizing Geographic Information System (GIS) software, specifically ArcGIS. The research was conducted in several stages: (i) The initial stage focused on data collection, which included the creation of elevation, slope, and soil type maps, as well as the acquisition of satellite imagery to inform land use analysis. (ii) Subsequently, the maps and information obtained in the first stage were utilized to develop the Land Map Unit (SPL). This SPL map served as a critical reference during field surveys that gathered morphological data, encompassing biophysical characteristics such as elevation, slope, rainfall, temperature, humidity, drainage, and additional factors. Soil samples were collected from each designated area using a soil drill to evaluate land suitability. The data obtained from the analysis facilitated the development of a comprehensive soil profile. The physical properties assessed

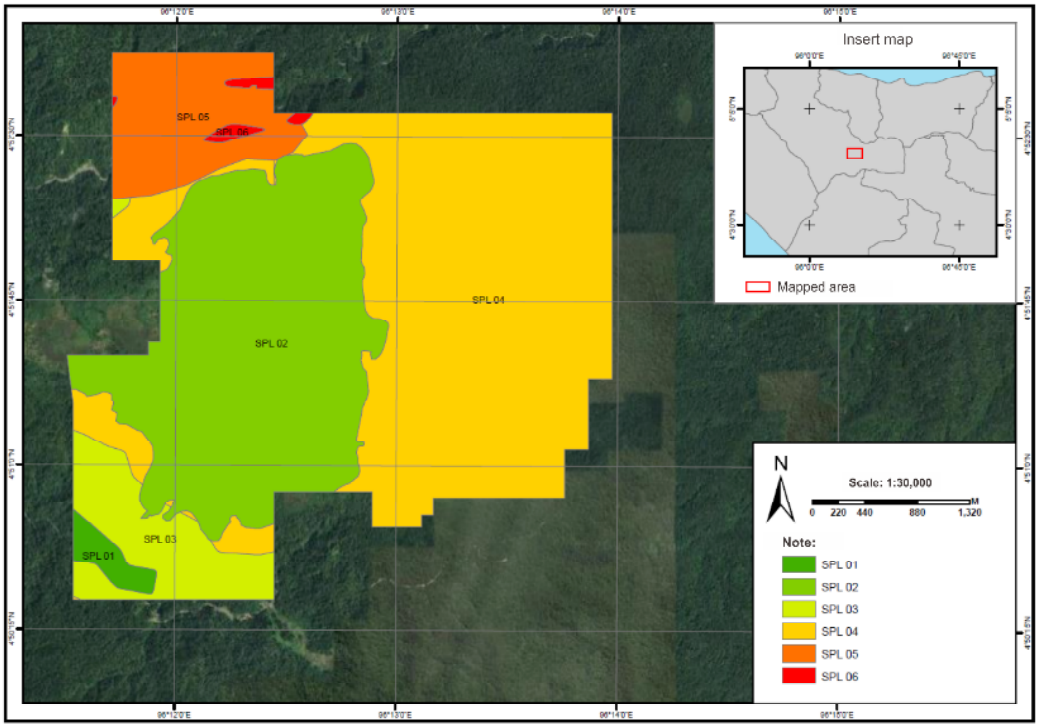

Figure 2. SPL map in Geumpang Subdistrict

from the samples extracted during the boring process included soil depth, texture, and overall fertility. The subsequent phase involves conducting a laboratory analysis of the chemical properties of the topsoil. This will focus on samples taken from a depth of 0-30 cm, with the aim of determining the precise level of soil fertility. For laboratory analysis, one kilogram of soil was collected from each SPL. (iii) Finally, the land morphology data and results from soil analysis, collectively referred to as land characteristic data, were assessed against the suitability criteria for Arabica coffee, based on the provisions outlined in the Indonesian Minister of Agriculture Regulation (Permentan) No. 49 of 2014, which pertains to Technical Guidelines for Good Agricultural Practices on Coffee.

The data collected from the field survey, along with the results of the soil sample analyses conducted in the laboratory, were evaluated for land suitability. This assessment utilized a classification method for coffee plants developed by the FAO (FAO, 1976). In Indonesia, the Center for Agricultural Land Resources Research and Development (BBSDLP: *Balai Besar Sumberdaya Lahan Pertanian*), based in Bogor, has developed a comprehensive method for classifying land suitability for coffee cultivation (Wahyunto *et al.,* 2016). As the leading reference institution for agricultural land in the country, BBSDLP collaborated closely with the Food and Agriculture Organization (FAO) and employed the FAO framework in formulating this classification methodology. The assessment of land suitability for coffee cultivation was conducted and subsequently compared with the land suitability data presented in the Indonesian Minister of Agriculture Regulation (Permentan) No. 49 of 2014 (see Table 1).

Table 1. Criteria for assessing land suitability for coffee cultivation

Parameter	Land suitability class			
	S1	S2	S3	N
1. Climate				
a. Annual rainfall (mm.year^{-1})	1,500-2,000 2,000-2,500	1,250 2,500-3,000	1,250 > 3,000	< 1,000
b. Dry month (month.year^{-1}) (< 60 mm.month^{-1})	2-3	3-4	4-5 1-2	> 5 < 1
2. Landform morphology				
a. Altitude (asl)				
- Robusta coffee	300-500	500-600 100-300	600-700 0-100	> 700
- Arabica coffee	1,000-1,500	850-1,000 1,500-1,700	650-850 1,750-2,000	< 650 > 2,000
b. Land slope (%)	0-8	8-25	25-45	> 45
3. Soil physical properties				
a. Soil texture	sandy loam clay loam silt loam silty clay loam	loamy sand sandy clay silty clay	clay	sand heavy clay
b. Drainage condition	good	quite good	rather bad bad	very bad flooding
c. Effective soil depth (cm)	> 150	100-150	60-100	< 60
d. Percentage of surface rock fragments (%)	0	0-3	3-15	> 15
4. Soil chemical properties				
a. pH	5.5-6.0	6.1-7.0 5.0-5.4	7.1-8.0 4.0-4.9	> 8.0 < 4.0
b. C-Organic content (%)	2-5	1-2 5-10	0.5-1.0 10-15	< 0.5 > 15
c. N (%)	> 0.21	0.1-0.2	< 0.1	-
d. Cation exchange capacity (me. 100 g^{-1})	> 15	10-15	5-10	< 5
e. Al saturation (%)	< 5	5-20	20-60	> 60
f. Exchangeable K (me %)	> 0.3	0.1-0.3	< 0.1	-
g. Base saturation (%)	> 35	20-35	< 20	-

RESULTS AND DISCUSSION

Pidie Regency, located in Aceh Province, is predominantly an agricultural area with a population exceeding 430,000 residents (BPS, 2022). The socio-economic framework of the community is primarily characterized by the agricultural and plantation sectors. Geumpang Subdistrict, which is part of Pidie, is situated in the Bukit Barisan mountain range, where a significant portion of the population relies on rice farming and traditional gardens for their economic sustenance. Within Geumpang Subdistrict, the SP III and SP V transmigration areas are designated as cultivation zones as per the spatial planning regulations (Qanun Kabupaten Pidie, 2014). The spatial arrangement categorizes the region into two distinct zones: protected and cultivation areas. The cultivation zones are intended for settlements and agricultural activities, following principles of efficiency and sustainability (Qanun Kabupaten Pidie Jaya, 2021). Conversely, Geumpang Subdistrict's classification as a partially protected zone necessitates the adoption of environmentally friendly and conservative agricultural practices. According to data from the Pidie Agriculture Department in 2023, the total area dedicated to coffee plantations in this region reaches approximately 10,287 hectares, exclusively cultivated with Robusta coffee. Nevertheless, field surveys indicate

that the SP III and SP V areas have elevations ranging from 910 to 1,100 m above sea level (asl.), accompanied by a stable tropical humid climate. These specific conditions are highly conducive for cultivating Arabica coffee, which thrives at elevations of 900 to 1,500 m asl. and requires relatively consistent temperatures (Wintgens, 2004; Ditjenbun, 2014). This information highlights Geumpang's potential as an emerging center for Arabica coffee production in Aceh.

Evaluation of Land Suitability for Arabica Coffee Plantation

Several parameters have been observed in both field and laboratory and have been categorized into four distinct groups: climate, land morphology, physical properties of soil, and chemical properties of soil. These categorizations are consistent with the guidelines established by the Indonesian Ministry of Agriculture Regulation (Permentan) (2014) concerning good agricultural practices for coffee cultivation.

- Climate

The evaluation of land suitability indicates that all Land Map Units (SPL) within the study area receive an annual rainfall exceeding 3,000 mm with less than one dry month, resulting in consistent rainfall throughout the year (Table 1). The analysis reveals that the land in Geumpang Subdistrict is categorized as unsuitable (N) for Arabica coffee cultivation, according to Permentan (2014). The optimal conditions for Arabica coffee cultivation, classified as S1, require annual rainfall of 1,500–2,000 mm and 2–3 dry months (Ditjenbun, 2014; Permentan, 2014). The climate plays a pivotal role in the growth, development, and productivity of coffee plants. Sufficient solar energy is essential for supporting photosynthesis and transpiration processes (Baon, 2016). Furthermore, coffee plants necessitate annual rainfall that exceeds their evapotranspiration levels for optimal growth and yield. Arabica coffee plants require approximately 1,400 to 2,000 mm of annual rainfall, with a minimum of 800 to 1,000 mm, while Robusta coffee needs between 2,000 and 2,500 mm, with a minimum of 1,200 mm, with the dry season lasting 1 to 3 months for Arabica coffee and 2 to 3 months for Robusta coffee. Rainfall levels below these minimums can negatively impact coffee production. For Arabica, a dry season lasting up to three months is beneficial for productivity. Although Robusta also benefits from a dry season to stimulate flowering, its fruits take longer to ripen compared to Arabica. The acceptable length of the dry season for Robusta depends on its specific genotype (Ditjenbun, 2014; Schroth *et al.,* 2015; Pujianto, 2016).

Aceh Province holds the distinction of being the third largest coffee producing region in Indonesia and is particularly renowned for its specialty Arabica coffee from the Kopi Gayo production center (Ditjenbun, 2025). This center is located in the Gayo highlands, which encompass the regencies of Aceh Tengah, Bener Meriah, Gayo Lues, and Pidie. According to data from the Indonesian Meteorology, Climatology, and Geophysics Agency (BMKG: *Badan Meteorologi, Klimatologi, dan Geofisika*), the average annual rainfall recorded from 1991 to 2020 in these four districts is as follows: 2,529 mm for Aceh Tengah, 2,278 mm for Bener Meriah, 2,720 mm for Gayo Lues, and 2,576 mm for Pidie (BMKG, 2021). Collectively, these Arabica coffee production centers experience an average annual rainfall of less than 3,000 mm.

Excessive rainfall is closely linked to significant nutrient loss in soil, primarily through processes such as leaching and erosion. Leaching leads to the depletion of base cations, resulting in increased soil acidity. Erosion, on the other hand, tends to occur in regions with steep slopes (Pujianto, 2016). Additionally,

excessively humid environmental conditions do not support the optimal growth of Arabica coffee. These plants require a defined dry period to facilitate flower initiation and ensure uniform fruit ripening, which is crucial for minimizing the risk of disease outbreaks. According to Morales Pena *et al.* (2024), Arabica coffee ideally requires an annual rainfall range of 1,200 to 1,800 mm, with a well-distributed pattern throughout the year, along with a dry season lasting 2 to 4 months to effectively trigger flowering.

- Landform morphology

The topographical conditions observed in the Geumpang Subdistrict reveal a diverse landscape (Table 2). The area features hilly regions with slopes exceeding 45% (SPL 1, SPL 6), gently undulating terrain with a slope of 24% (SPL 4), and flat land with slopes ranging from 6% to 8% (SPL 2, SPL 3, SPL 5). The altitudes in this subdistrict vary between 900 m and 1,100 m asl. Notably, SPL 1 and SPL 3 are situated at altitudes of 910 m and 915 m, respectively, while SPL 2, SPL 4, SPL 5, and SPL 6 are located at altitudes of 1,090 m, 1,100 m, 1,090 m, and 1,080 m asl., respectively. Based on land suitability classifications, SPL 1 and SPL 6 are categorized as unsuitable (N) for cultivation due to their steep slopes of more than 45%. In contrast, SPL 2, SPL 3, SPL 4, and SPL 5 are identified as suitable for the cultivation of Arabica coffee (Table 3).

In Indonesia, the optimal growth of Arabica coffee occurs at altitudes ranging from 1,000 to 1,500 m asl. (Ditjenbun, 2014). The altitude at which coffee is cultivated significantly influences both the growth characteristics of the Arabica plant and the quality of the coffee beans produced. Specifically, at medium altitudes (1,000–1,400 m), the plants tend to develop a greater number of branches and yield higher outputs (Hanan *et al.*, 2025). Furthermore, soils found at these

Table 2. Land characteristics observed in Geumpang Subdistrict

No.	Parameter	Land suitability class and area					
		SPL 1	SPL 2	SPL 3	SPL 4	SPL 5	SPL 6
		19.99 ha	533.12 ha	114.16 ha	731.94 ha	143.33 ha	9.61 ha
1.	Climate						
	a. Annual rainfall (mm.year^{-1})	> 3,000	> 3,000	> 3,000	> 3,000	> 3,000	> 3,000
	b. Dry month (month.year^{-1})	< 1	< 1	< 1	< 1	< 1	< 1
2.	Landform morphology						
	a. Topography	hilly	flat	flat	rollings hills	flat	hilly
	b. Altitude (m asl.)	910	1,090	915	1,100	1,090	1,080
	c. Land slope (%)	> 45	7	8	24	6	> 45
3.	Soil physical properties						
	a. Soil texture	silty clay loam	silty clay loam	silty clay loam	clay	clay	clay loam
	b. Drainage condition	good	quite good	good	quite good	good	good
	c. Effective soil depth (cm)	58	102	84	110	117	80
	d. Percentage of surface rock fragments (%)	0	3	0	2	0	0
4.	Soil chemical properties						
	a. pH	4.67	5.23	4.53	5.52	4.15	4.37
	b. Organic matter content (%)	7.36	7.36	8.97	11.93	11.89	11.77
	c. N (%)	0.86	0.51	0.74	1.31	1.37	1.18
	d. Cation exchange capacity (me. 100 g^{-1})	43.20	33.60	34.80	66.00	13.20	63.60
	e. Al saturation (%)	6.95	3.27	17.05	0.44	12.56	5.88
	f. Exchangeable K (me %)	0.38	0.43	0.32	0.89	0.76	0.86
	g. Base saturation (%)	17.20	13.36	10.23	26.23	66.29	20.25

medium to high altitudes exhibit improved physico-chemical quality and enhanced root microbial diversity, both of which support sustainable coffee cultivation practices and contribute to coffee cupping quality (Ge *et al*., 2023; Abubakar *et al*., 2024). In terms of land slope, cultivating coffee on slopes of less than 8% facilitates more effective land management. On the other hand, steeper slopes can lead to increased cultivation costs (Baon, 2016). This observation is consistent with findings by Arvi *et al*. (2019), who identified that the highest production of Arabica coffee beans in the Gayo Lues Subdistrict in 2018 was achieved at altitudes between 1,000 and 1,200 m and on slopes with a gradient of less than 8%. Additionally, it is important to recognize that highland slopes are prone to erosion, which may hinder coffee plant growth (Marianto *et al.*, 2022). Although the implementation of terraces can mitigate some challenges associated with steep slopes, this approach typically results in higher associated costs.

- Soil physical properties

The physical properties of soil play a crucial role in agricultural practices and include factors such as soil texture, water drainage, effective depth, and the percentage of rocks on the soil surface. According to the coffee Good Agricultural Practices (GAP) guidelines (Ditjenbun, 2014; Permentan, 2014), Arabica coffee attains optimal growth under specific soil conditions: (i) ideal soil textures include sandy loam, loamy sand, loamy silt, silty sand, and silty clay; (ii) well-drained soil; (iii) a minimum effective soil depth of 100 cm; and (iv) a rock percentage on the surface ranging from 0% to 3%. An analysis conducted on the soil in SPL 1–6, located in Geumpang Subdistrict, revealed that the predominant soil textures are clay and silty clay loam, both of which are conducive to Arabica coffee cultivation. The drainage conditions are classified as adequate to good, with effective soil depths varying from 58 cm to 117 cm. Additionally, the percentage of rocks present on the soil surface remains relatively low, between 0% and 3%. It is important to note that the physical properties of the soil impose limitations, particularly regarding effective soil depth. SPL 1, having an effective soil depth of less than 60 cm, is classified as unsuitable (N) for Arabica coffee cultivation. Conversely, SPL 6, with an effective depth of 80 cm, is classified as marginally suitable (S3). The soils in SPL 2 through SPL 5 are deemed suitable for the cultivation of Arabica coffee.

Soil texture and effective depth are critical factors influencing plant root development. Sandy loam soil is particularly advantageous as it offers adequate drainage and aeration, which facilitate soil cultivation and enable effective root penetration for optimal nutrient absorption (Manfarizah *et al.*, 2024; Santi *et al.*, 2024). In contrast, compacted soil can impede the growth of coffee roots (Ramos *et al.*, 2023), while soils with high clay content may negatively affect crop yields (Huu Le *et al.*, 2022). Moreover, effective soil depth supports the development of deeper root systems, which is essential for enhancing crop productivity. It is also important to note that the presence of rocks at the soil surface can reduce effective soil depth and aeration levels, potentially leading to water accumulation and further restricting plant root growth.

- Soil chemical properties

The following report presents an analysis of the chemical properties of soil, specifically focusing on pH, organic matter content, nitrogen content, cation exchange capacity, aluminum saturation level, exchangeable K, and base saturation. Arabica coffee flourishes optimally in soil conditions characterized by a pH between 5.0 and 7.0, organic matter content ranging from 1% to 5%, nitrogen

content exceeding 0.21%, cation exchange capacity greater than 15 cmol kg^{-1}, aluminum saturation levels below 1–3%, and base saturation levels between 5% and 20% (Ditjenbun, 2014; Permentan, 2014). Analysis results indicate that SPL 1, SPL 3, SPL 5, and SPL 6 have pH values of 4.67, 4.53, 4.15, and 4.37, respectively. Only SPL 2 and SPL 4 have pH values greater than 5, measuring 5.23 and 5.52, respectively. The organic matter content in SPL 1, SPL 2, and SPL 3 ranges from 7.36% to 8.97%, categorizing it as suitable for Arabica coffee cultivation. In contrast, SPL 4, SPL 5, and SPL 6 present organic matter content ranging from 11.77% to 11.93%, categorizing them as marginally suitable. The nitrogen content, cation exchange capacity, aluminum saturation, and exchangeable K levels are deemed suitable for Arabica coffee cultivation, as shown in Table 2, according to the Permentan (2014). SPL 1, SPL 2, and SPL 3 have marginal base saturation levels, with values below 20% (17.20%, 13.36%, and 10.23%, respectively). In comparison, SPL 4, SPL 5, and SPL 6 have base saturation levels that are suitable for growing Arabica coffee.

The chemical properties of soil are integral to the growth of coffee plants and the development of their distinctive flavor profiles. The pH level of the soil significantly influences the availability of essential nutrients for the plants, while the content of organic matter plays a vital role in enhancing soil structure and nutrient supply (Prasetia *et al.*, 2025). Research indicates that an increase in organic matter correlates positively with a rise in cation exchange capacity, which in turn facilitates the absorption of potassium (K) and calcium (Ca) nutrients. Conversely, low soil pH can lead to an increase in toxic aluminum saturation around coffee roots, inhibit the absorption of macronutrients, and decrease soil microbial activity, all of which can negatively impact productivity (Santi *et al.*, 2024; Nguyen Van *et al.*, 2025). Elevated levels of cation exchange capacity, base saturation, and potassium content contribute to improved nutrient availability in the soil, thereby enhancing coffee production outcomes (Prasetia *et al.*, 2025).

Land Suitability of Geumpang Subdistrict

Based on the results of the conducted analysis, the land in SP III and SP V of Geumpang Subdistrict, Pidie Regency, Aceh, has been classified as unsuitable (N) for Arabica coffee cultivation, as detailed in Table 2. The primary constraint on suitability is the high level of annual rainfall, which exceeds 3,000 mm, accompanied by a dry season lasting less than one month. This results in a uniform distribution of rainfall throughout the year, creating challenging natural conditions to manage. Despite these constraints, the land in Geumpang Subdistrict is assessed as generally suitable to marginally suitable when considering land morphology and the physical and chemical properties of the soil. Should this area be designated as a development zone for Arabica coffee, the implementation of an agroforestry system is strongly recommended. Such systems can significantly improve soil moisture retention, reduce evapotranspiration, and enhance water infiltration into the soil (Nasiro, 2024). Furthermore, to mitigate surface runoff and soil erosion associated with heavy rainfall events, it is advisable to construct terraces and contour channels. This approach will help increase water availability in the root zone while minimizing soil erosion risks (Blanco-Sepulveda *et al.*, 2024).

CONCLUSIONS

The SP III and SP V transmigration areas located in Geumpang Subdistrict have been evaluated and determined to be unsuitable for the cultivation of Arabica coffee. This

Table 3. Land suitability class of Geumpang Subdistrict

Parameter	Land suitability class and area					
	SPL 1	SPL 2	SPL 3	SPL 4	SPL 5	SPL 6
	19.99 ha	533.12 ha	114.16 ha	731.94 ha	143.33 ha	9.61 ha
1. Climate						
a. Annual rainfall	N	N	N	N	N	N
b. Dry month	N	N	N	N	N	N
2. Landform morphology						
a. Topography	S2	S1	S2	S1	S1	S1
b. Altitude	S2	S1	S2	S1	S1	S1
c. Land slope	N	S1	S1	S2	S1	N
3. Soil physical properties						
a. Soil texture	S1	S1	S1	S1	S1	S1
b. Drainage condition	S1	S1	S1	S1	S1	S3
c. Effective soil depth	N	S2	S2	S2	S2	S3
d. Percentage of surface rock fragments	S1	S2	S1	S2	S1	S1
4. Soil chemical properties						
a. pH	S3	S2	S3	S1	S3	S3
b. Organic matter content	S2	S2	S2	S3	S3	S3
c. N	S1	S1	S1	S1	S1	S1
d. Cation exchange capacity	S1	S1	S1	S1	S2	S1
e. Al saturation	S2	S1	S2	S1	S2	S2
f. Exchangeable K	S1	S1	S1	S1	S1	S1
g. Base saturation	S3	S3	S3	S2	S1	S2
Suitability classification	N	N	N	N	N	N

Notes: S1 = Very suitable; S2 = Quite suitable; S3 = Marginally suitable; N = Not suitable.

conclusion is based on several critical factors, including an annual rainfall exceeding 3,000 mm, which is distributed evenly throughout the year, resulting in less than one dry month. Furthermore, the morphology of the land presents significant challenges; specifically, areas SPL 1 and SPL 6 exhibit slope gradients that surpass 45%. In addition, the SPL 1 area is constrained by an effective soil depth of less than 60 cm. From a soil chemical property, there are notable limitations in areas SPL 1 and SPL 3, characterized by low pH and base saturation levels. Similarly, both SPL 5 and SPL 6 have insufficient pH levels and organic matter content that impede the potential for successful Arabica coffee cultivation.

REFERENCES

Abubakar, Y.; A. Anhar; A. Baihaqi & A.M. Mushlih (2024). Influence of farm altitude and variety on quality of Arabica coffee cherry and bean grown in Gayo highland, Indonesia. *International Journal of Design & Nature and Ecodynamics,* 19(3), 1033–1041.

Arvi, D.; Syakur & A. Karim (2019). Hubungan ketinggian tempat dan kelerengan terhadap produksi kopi Arabika Gayo 1 di Kabupaten Gayo Lues. *Jurnal Ilmiah Mahasiswa Pertanian,* 4(4), 596–602.

Auliansyah, G.; Fachruddin & Y. Yunus (2019). Evaluasi kesesuaian lahan pada tanaman kopi Arabika (*Coffea Arabica* L.) organic menggunakan sistem informasi geografis (SIG) di Kecamatan Pegasing Kabupaten Aceh Tengah. *Jurnal Ilmiah Mahasiswa Pertanian,* 4(2), 339–348.

Baon, J.B. (2016). Lahan untuk Penanaman Kopi. p. 163–182. ***In:*** *Kopi: Sejarah, Botani, Proses Produksi, Pengolahan, Produk Hilir, dan Sistem Kemitraan.* Gadjah Mada University Press. Yogyakarta, Indonesia.

Blanco-Sepulveda, R.; F. Lima & A. Aguilar-Carrillo (2024). An assessment of the shade and ground cover influence on the

mitigation of water-driven soil erosion in a coffee agroforestry system. *Agroforestry System,* 98, 1771–1782.

BMKG (2021). *Peta Rata-Rata Curah Hujan dan Hari Hujan Periode 1991–2020 Indonesia*. Pusat Informasi Perubahan Iklim BMKG. Jakarta, Indonesia.

BPS (2022). Kabupaten Pidie Dalam Angka: Data Kependudukan. Badan Pusat Statistik. Jakarta, Indonesia.

BPS (2023). *Statistik Kopi Indonesia 2022*. Badan Pusat Statistik Republik Indonesia. Jakarta, Indonesia.

Ditjenbun (2014). *Pedoman Teknis Budidaya Kopi yang Baik (Good Agriculture Practices/ GAP on Coffee)*. Direktorat Jenderal Perkebunan Kementerian Pertanian Republik Indonesia. Jakarta, Indonesia.

Ditjenbun (2023). *Statistik Perkebunan Unggulan Nasional 2021–2023*. Direktorat Jenderal Perkebunan Kementerian Pertanian Republik Indonesia. Jakarta, Indonesia.

Ditjenbun (2024). *Statistik Perkebunan Jilid I 2022–2024*. Direktorat Jenderal Perkebunan Kementerian Pertanian Republik Indonesia. Jakarta, Indonesia.

Ditjenbun (2025). *Statistik Perkebunan Jilid I 2023–2025*. Direktorat Jenderal Perkebunan Kementerian Pertanian Republik Indonesia. Jakarta, Indonesia.

Djaenuddin, D; H. Marwan; H.S.A. Mulyani & N. Suharta (2000). *Kriteria Kesesuaian Lahan Untuk Komoditas Pertanian Versi 3.0*. Pusat Penelitian Tanah dan Agroklimat. Bogor, Indonesia.

FAO (1976). *A framework for land evaluation.* Food and Agriculture Organization of the United Nations. Rome, Italy.

Ge, Y.; F. Zhang; C. Xie; P. Qu; K. Jiang; H. Du; M. Zhao; Y. Lu; B. Wang; X. Shi; X. Li & C. Zhang (2023). Effects of different altitudes on *Coffea arabica* rhizospheric soil chemical properties and soil microbiota. *Agronomy,* 13(2), 471.

Hanan, A.; A. Anhar; Y. Abubakar & A. Karim (2025). A Study on the yield of Arabica coffee in Gayo highland Indonesia: the significance of altitude and varieties. *Tuijin Jishu/Journal of Propulsion Technology,* 46(2), 631–643.

Huu Le, V.; C.T. Truong; A. Hung Le & T. Nguyen (2022). A Combination of shade trees and soil characteristics may determine Robusta coffee (*Coffea canephora*) yield in a tropical monsoon environment. *Agronomy,* 13, 65.

Manfarizah, M.; A. Karim; H. Basri; M. Muyassir; M. Rusdi & A. Mulia (2024). Characteristics of soil physical and chemical properties on Arabica coffee land in Bener Meriah Regency. *IOP Conference Series: Earth and Environmental Science (The 5th ICAGRI 2023)*, 1297, 012034.

Marianto, H.; M. Mujiyo; S. Sutarno; L.Z. Wijaya; K.A. Syamsuddin & B.D.E.P. Nugroho (2022). Budidaya kopi Arabika di Desa Jayagiri sebagai hasil penilaian evaluasi kesesuaian lahan. *PRIMA: Journal Empowering and Services,* 6(1), 30–36.

Morales-Pena, V.H.; A.M. Garces; E.M.V. Filho; M.V. Sanchez; W.W.P. Pachay & E.C. Ares (2024). The Phenology of *Coffea arabica* var. Esperanza L4A5 under different agroforestry associations and fertilization conditions in the Caribbean Region of Costa Rica. *Agriculture,* 14, 1988.

Nasiro, K. (2024). The Benefits of agroforestry coffee production systems: a review. *World Journal of Food Science and Technology,* 8(4), 86–105.

Nguyen Van, L.; L. Herrmann; T.L. Dinh; C. Nguyen Van; L. Nguyen Van; A. Enez; L. Brau & D. Lesueur (2025). Liming effect on soil chemical and biological properties, pests and diseases, and crop yields in Robusta coffee and black pepper in Vietnam. *Soil Research,* 63, SR24143.

Permentan (2014). *Peraturan Menteri Pertanian No. 49/Permentan/OT.140/4/2014 tentang Pedoman Teknis Budidaya Kopi yang Baik (Good Agriculture Practices on Coffee).* Direktorat Jenderal

Perkebunan Kementerian Pertanian Republik Indonesia. Jakarta, Indonesia.

Prasetia, R.; S. Kurniawan & K. Fibrianto (2025). The Impact of the chemical characteristics of the soil in an agroforestry system on the sensory quality of Robusta coffee. *BIO Web Conferences (ICGAB 2024),* 165, 04001.

Pujianto (2016). Cekaman Air pada Tanaman Kopi. p. 382-401. ***In:*** *Kopi: Sejarah, Botani, Proses Produksi, Pengolahan, Produk Hilir, dan Sistem Kemitraan.* Gadjah Mada University Press. Yogyakarta, Indonesia.

Qanun Kabupaten Pidie (2014). *Rencana Tata Ruang Wilayah Kabupaten Pidie Tahun 2014–2034.* Qanun Kabupaten Pidie Nomor 5 Tahun 2014. Aceh, Indonesia.

Qanun Kabupaten Pidie Jaya (2021). *Perlindungan Lahan Pertanian Pangan Berkelanjutan.* Qanun Kabupaten Pidie Jaya Nomor 1 Tahun 2021. Aceh, Indonesia.

Ramos, E.G.; V.M.S. Barros; J.D.B. Miranda; L.M.R. Silva; J.C.L. Nevres; R.M.S.A. Meira & T.S. de Oliveira (2023). Physiological and morphological responses of Arabica coffee cultivars to soil compaction. *Revista Brasileira de Ciencia do Solo*, 47, e0230046.

Santi, R.; N.S. Khodijah & S. Cahyani (2024). Physical and chemical of soil properties area coffee in several Banjar Villages, Bangka Regency. *Jurnal Lahan Suboptimal: Journal of Suboptimal Lands,* 13(1), 1–8.

Schroth, G.; P. Laderach; A.I. Martinez-Valle & C. Bunn (2015). *Climate Vulnerability and Adaptation of the Smallholder Cocoa and Coffee Value Chains in Liberia. Working Paper No. 134.* CGIR Research Program on Climate Change, Agriculture, and Food Security (CCAFS); International Fund for Agricultural Development (IFAD). Copenhagen, Denmark.

Vania, S. (2021). Analisis terhadap program transmigrasi serta pengembangan wilayah di unit pemukiman transmigrasi Geumpang II SP 3 Provinsi Aceh. *Kadarkum: Jurnal Pengabdian Kepada Masyarakat,* 2(2), 113–23.

Wahyunto; Hikmatulloh; E. Suryani; C. Tafakresnanto; S. Ritung; A. Mulyani; Sukarman; K. Nugroho; Y. Sulaeman; Y. Apriyana; Suciantini; A. Pramudia; Suparto; R.E. Subandiono; T. Sutriadi & D. Nursyamsi (2016). *Petunjuk Teknis Pedoman Penilaian Kesesuaian Lahan Untuk Komoditas Pertanian Strategis Tingkat Semi Detail Skala 1:50,000.* Balai Besar Litbang Sumberdaya Lahan Pertanian-Badan Penelitian dan Pengembangan Pertanian. Bogor, Indonesia.

Wintgens, J.N. (2004). *Coffee: Growing, Processing, Sustainable Production.* Wiley-VCH Verlag GmbH & Co. KGaA. Corseaux, Switzerland.

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