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Land Suitability Evaluation for Durian (*Durio zibethinus* Murr.) Cultivation Based on Nutrient Retention

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ABSTRACT

*Indonesia possesses vast land resources, offering significant potential for agricultural development. Among high-value commodities, durian (*Durio zibethinus *Murr.) is widely cultivated. Bumiaji District in Batu City, characterized by hilly topography and extensive agricultural land, serves as a prominent durian production center. Optimizing durian productivity, however, requires a thorough understanding of land suitability based on soil characteristics. This study evaluated land suitability for durian cultivation in Bumiaji District, focusing on key soil chemical properties, including soil pH, cation exchange capacity (CEC), base saturation (BS), and organic carbon (C-organic) content. The research was conducted using a survey method with purposive random sampling based on land mapping units (LMUs). Results indicated that most areas were classified as highly suitable (S1) based on CEC and organic carbon parameters, with CEC values ranging from 18.89 to 35.97 cmol/kg and C-organic levels above 1.2%. However, limitations were noted for pH and base saturation, with some areas classified as moderately (S2) or marginally suitable (S3). Improving land suitability can be achieved through targeted soil management strategies, such as liming with dolomite to enhance pH and base saturation. The findings of this study are expected to serve as a reference for implementing sustainable land management practices aimed at boosting durian productivity in Bumiaji District.*

1. INTRODUCTION

Indonesia is a country with a vast territory and abundant natural resources. The total area of agricultural and previously utilized land reaches approximately 80 million hectares, encompassing various uses such as rice fields, plantations, home gardens, drylands, pastures, production forests, fishponds, and other water bodies (BBSDLP, 2008). These lands are used for cultivating both seasonal crops, such as rice and corn, and perennial crops, such as avocado, durian, and clove.

Bumiaji District is located in a hilly region, with all its villages situated on uplands. This contrasts with Batu and Junrejo Districts, which feature a mix of plains and hills. Bumiaji covers an area of approximately 127.978 km², accounting for 64.28% of Batu City, and is bordered by Batu District to the north, Junrejo District to the east, Blitar and Malang Regencies to the south, and Malang Regency to the west (BPS, 2023). The district has significant agricultural potential, with farmland covering 2,213 hectares (BPS, 2023). Key crops include seasonal crops such as corn and rice, and perennial crops such as avocado, rambutan, and durian, with durian ranking third in productivity after apple and avocado. Durian plantations are evenly distributed across the area, covering a total of 2,286.39 ha.

Despite this potential, durian growth in Bumiaji has declined, largely because farmers tend to focus solely on maintaining durian trees without sufficient attention to soil and surrounding land conditions. Understanding these factors is crucial for identifying existing constraints and developing strategies to improve yields. Land suitability assessment based on the growth requirements of durian is therefore essential to identify limitations affecting productivity (Krisanti & Setiawan, 2023).

Land suitability evaluation assesses the potential and appropriateness of a given area for specific land uses, aiming to minimize the risk of failure and enhance the economic value of the land. This assessment considers landscape characteristics, soil types, and the soil's capacity to retain essential nutrients (N, P, K, Ca, Mg, and micronutrients), which is a key factor in determining suitability classifications (Iqbal *et al*., 2018; Alridiwirsah *et al*., 2022). This study aims to provide data on soil chemical properties for land suitability evaluation, enabling more effective land management to increase durian production in Bumiaji District, as well as providing baseline information on nutrient retention in the surrounding land.

2. MATERIALS AND METHODS

This study was carried out from August to November 2023 in Bumiaji District, Batu City. The district covers an area of approximately 127.978 km², representing 64.28% of the total area of Batu City.

The research employed a purposive random sampling method within a survey approach. Field surveys were conducted through direct observations and soil sampling. Sampling points were determined using purposive random sampling, in which samples are selected randomly based on specific, pre-defined criteria. The selection of sampling locations was guided by the Land Map Unit (LMU) to ensure representative coverage of the study area.

2.1. Land Map Unit Delineation

The Land Map Unit (LMU) was delineated by overlaying the administrative map, slope map, and land use map of Bumiaji District, Malang Regency (Figure 1). The resulting LMU map served as the observational unit for soil sampling. The LMU map was developed using Geographic Information System (GIS) tools, specifically ArcGIS version 10.8.

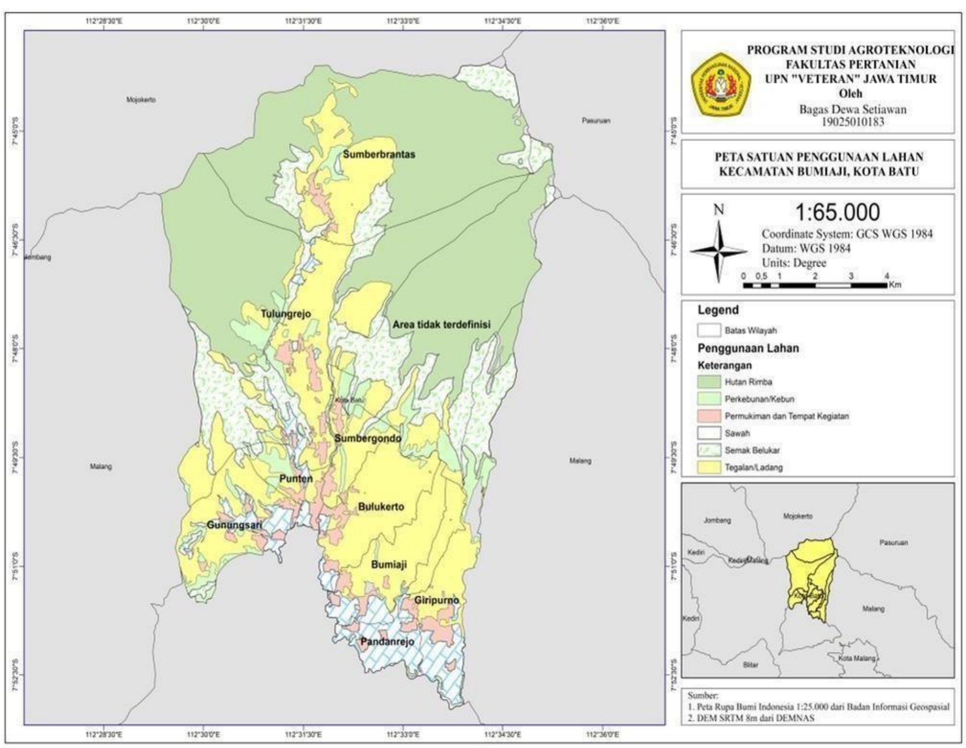

Figure 1. Land map unit delineation

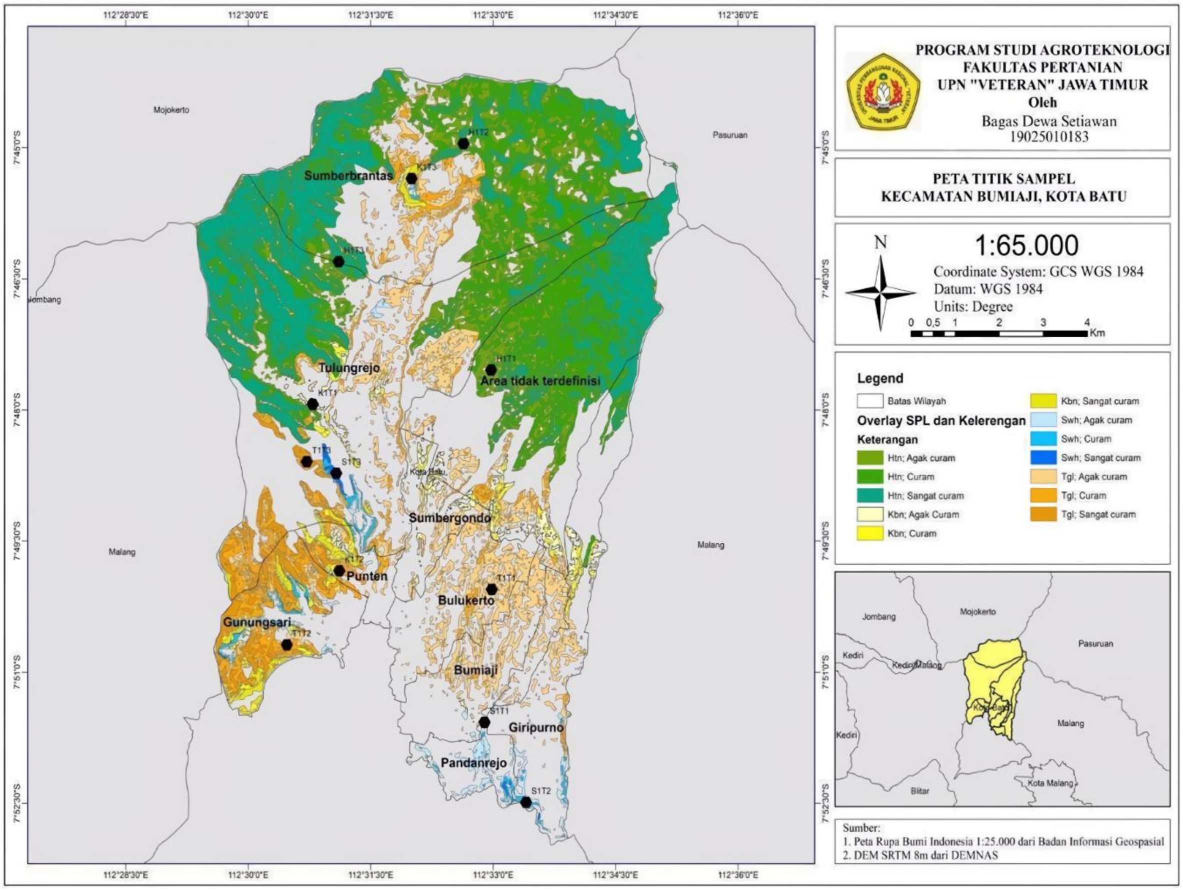

Figure 2. Sample point map

2.2. Determination of Sampling Points

Soil sampling points were determined using a purposive sampling method based on the land use map obtained from overlaying land use data in Bumiaji District. The processed map identified four main land use types: forest, dry field (*tegalan*), plantation, and paddy field. Each land use type was replicated three times and sampled at two soil depths (0–30 cm and 30–60 cm). Samples from the same land use type and depth were then composited into a single soil sample, resulting in a total of 12 Land Map Units (LMUs) to be observed and analyzed (Figure 2).

2.3. Observation Parameter and Data Analysis

The observed parameters consisted of soil chemical properties, including organic carbon (C), pH in H_2O, cation exchange capacity (CEC), and base saturation. The analyses were conducted using the methods as summarized in Table 1. The collected data were processed and analyzed by comparing the measured soil properties with the land suitability requirements for durian cultivation, as outlined by Djaenuddin *et al*. (2011).

Table 1. Research parameter and analysis method

No	Type of analysis	Unit	Method	Reference
1	C-Organic	%	Walkley & Black	
2	pH H_2O	-	Glass Elektroda Leaching	Eviati *et al*. (2023)
3	CEC	$Cmol/kg^{-1}$		
4	Base saturation	%	NH_4OA_c	

Table 2. Land suitability requirements for durian cultivation (Djaenudin *et al*., 2011)

Land Characteristic	S1	S2	S3	S4
Average daily temperature (°C)	22 – 28	28 – 34 / 18 – 22	34 – 40 / 15 – 18	> 40 / < 15
Rainfall (mm)	1000 – 2000	500 – 1000 / 2000 – 3000	250 – 500 / 3000 – 4000	< 250 / > 4000
Drainage	Good to moderate	Slightly impeded	Impeded, slightly rapid	Very impeded, rapid
Texture	Fine, moderately fine, medium	-	Very fine, moderately coarse	Coarse
Coarse material (%)	< 15	15 – 35	35 – 55	> 55
Soil depth (cm)	> 50	> 50	30 – 50	< 30
Peat thickness (cm)	< 60	60 – 140	140 – 200	> 200
Peat thickness with mineral enrichment (cm)	< 140	140 – 200	200 – 400	> 400
Decomposition stage	Sapric +	Sapric, hemic +	Hemic, fibric +	Fibric
Clay CEC (cmol)	> 16	< 16	-	-
Base saturation (%)	> 35	20 – 35	< 20	-
pH H_2O	5.0 – 6.0	4.5 – 5.0	< 4.5	-
Organic C (%)	> 1.2	0.8 – 1.2	< 0.8	-
Salinity (dS/m)	< 4	4 – 6	6 – 8	> 8
Alkalinity/ESP (%)	< 15	15 – 20	20 – 25	> 25
Slope (%)	< 8	8 – 16	16 – 30	> 30
Erosion hazard	Very low	Low – moderate	Severe	Very severe
Inundation	F0	F1	F2	> F2
Surface rock (%)	< 5	5 – 15	15 – 40	> 40
Rock outcrop (%)	< 5	5 – 15	15 – 25	> 25
Land Characteristic	S1	S2	S3	N
Average daily temperature (°C)	22 – 28	28 – 34 / 18 – 22	34 – 40 / 15 – 18	> 40 / < 15

Note: S1 = Highly Suitable ; S2 = Moderately Suitable ; S3 =Marginally Suitable ; S4 = Not Suitable.

3. RESULTS AND DISCUSSION

3.1. General Condition of Bumiaji District Area

The general conditions of Bumiaji District indicate that all sampling sites contain a mixture of cultivated crops and natural vegetation. Andisols are the dominant soil type, with Inceptisols present in some observation sites. Each Land Map Unit (LMU) covers areas ranging from several to hundreds of hectares, which are owned by one or more families, with some areas being rented. Bumiaji District is a highland region, situated at approximately 1,700 meters above sea level, with an average daily temperature ranging from 17 to 24 °C. Additionally, several areas within the district are designated as water catchment zones.

Table 3. General condition of Bumiaji District Area

Land unit	Coordinate	Land use	Total Are Width (ha)
K1	7°44'30.1"S 112°27'42.1"E	Mixed orchard (durian, sengon wood, avocado)	167.10
K2	7°45'50.0"S 112°26'48.9"E	Mixed orchard (durian, avocado)	126.56
K3	7°46'40.2"S 112°29'10.5"E	Mixed orchard (durian, wild plants, rambutan)	82.55
T1	7°47'20.1"S 112°28'55.2"E	Cultivation of apple, orange, and durian	1,114.32
T2	7°48'05.3"S 112°29'35.0"E	Cultivation of apple, orange, durian, and horticultural crops	497.49
T3	7°48'55.0"S 112°30'10.2"E	Cultivation of apple, orange, durian, and coffee	229.95
H1	7°49'50.4"S 112°29'30.8"E	Mixed forest (durian, wild plants, teak)	790.02
H2	7°51'00.2"S 112°31'15.3"E	Mixed forest (durian, apple, mango)	1,938.99
H3	7°51'54.8"S 112°31'35.1"E	Mixed forest (wild plants, mango)	1,693.00
S1	7°53'05.3"S 112°31'01.9"E	Polyculture cultivation (rice, chili, and vegetables)	126.07
S2	7°55'18.0"S 112°32'39.1"E	Polyculture farming (rice, chili, and vegetables)	68.69
S3	7°56'08.5"S 112°35'49.9"E	Monoculture farming (rice)	19.88

Description: K: Garden; T: Dry land field; H: Forest; S: Rice field

Table 3 indicates that durian trees are present in almost all areas, with varieties including local durian and Montong. The maintenance practices carried out by farmers within each LMU are generally non-specific, meaning that all crop types receive similar treatment, although some areas receive additional care. According to Mbana (2021), Bumiaji District has significant potential for cultivating tropical fruits such as guava, durian, apple, and citrus, with certain areas suitable for further agricultural development.

3.2. Nutrient Retention Analysis

Nutrient retention refers to the soil's capacity to retain and supply essential nutrients required for plant growth and development. In the assessment of land suitability for durian cultivation, nutrient retention is evaluated based on several key indicators, including cation exchange capacity (CEC), base saturation, soil pH, and organic carbon content.

3.2.1. Cation exchange capacity

Cation exchange capacity (CEC) reflects the soil's ability to retain and exchange essential cation nutrients for plant growth. This capacity is influenced by several factors, including soil acidity (pH), organic matter content, clay mineral composition, and clay content (Supriyadi, 2009).

Based on the evaluation results, land suitability for durian cultivation in Bumiaji District is predominantly classified as S1 (highly suitable), covering an area of approximately 6,854.62 hectares. The CEC values in this region range from 18.89 to 35.97 cmol/kg, which fall into the moderate to high category. The highest CEC value was observed in Land Map Unit (LMU) H3 (35.97 cmol/kg), while the lowest value was recorded in LMU K1 (18.89 cmol/kg). According to Saputra *et al*. (2021), soils that are suitable for durian cultivation generally have CEC values exceeding 15 cmol/kg. Based on these findings, the CEC values in Bumiaji District meet the criteria for class S1 (highly suitable) for durian cultivation. Adequate CEC is essential for durian growth because it enhances nutrient retention, supports root and fruit development, and improves fertilizer use efficiency (Basuki *et al*., 2021).

Table 4. Cation exchange capacity

No	Land unit	CEC (cmol/kg^{-1})	Category	Criteria	Total Are Width (ha)
1	K1	18.89	Medium	S1 (Highly suitable)	167.10
2	K2	34.02	High	S1 (Highly suitable)	126.56
3	K3	26.08	High	S1 (Highly suitable)	82.55
4	T1	24.51	Medium	S1 (Highly suitable)	1,114.32
5	T2	31.08	High	S1 (Highly suitable)	497.49
6	T3	24.89	Medium	S1 (Highly suitable)	229.95
7	H1	31.08	High	S1 (Highly suitable)	790.02
8	H2	28.60	High	S1 (Highly suitable)	1,938.99
9	H3	35.97	High	S1 (Highly suitable)	1,693.00
10	S1	23.07	Medium	S1 (Highly suitable)	126.07
11	S2	28.78	High	S1 (Highly suitable)	68.69
12	S3	31.25	High	S1 (Highly suitable)	19.88

Description: K: Garden; T: Dry land field; H: Forest; S: Rice field

3.2.2. Base saturation

According to Sudaryono (2009), soil base saturation (BS) refers to the percentage of cation exchange capacity (CEC) occupied by base cations such as calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). This parameter is very important in determining fertilization requirements and estimating nutrient availability for plants. Base saturation reflects the proportion between base cations and acidic cations in the soil exchange complex. In general, base cations are essential nutrients required to support plant growth.

The land suitability level based on soil base saturation (BS) for durian in Bumiaji District is dominated by class S2, covering an area of 6,248.95 ha, with BS categorized as medium to low, ranging from 18.89% to 35.97%. The highest BS value was found in land map unit K1 at 48.27%, while the lowest BS value was in land map unit K2 at 24.40%.

Table 5. Base saturation

No	Land unit	BS (%)	Category	Criteria	Total Are Width (ha)
1	K1	48.27	Medium	S1 (Highly suitable)	167.10
2	K2	24.40	Low	S2 (moderately suitable)	126.56
3	K3	36.10	Low	S1 (Highly suitable)	82.55
4	T1	29.72	Low	S2 (moderately suitable)	1,114.32
5	T2	31.82	Low	S2 (moderately suitable)	497.49
6	T3	37.92	Low	S1 (Highly suitable)	229.95
7	H1	25.14	Low	S2 (moderately suitable)	790.02
8	H2	34.25	Low	S2 (moderately suitable)	1,938.99
9	H3	26.70	Low	S2 (moderately suitable)	1,693.00
10	S1	38.53	Low	S1 (Highly suitable)	126.07
11	S2	27.06	Low	S2 (moderately suitable)	68.69
12	S3	25.12	Low	S2 (moderately suitable)	19.88

Description: K: Garden; T: Dry land field; H: Forest; S: Rice field

This is possibly influenced by farmers' fertilization practices, which may lower BS values. Syamsiyah *et al*. (2023) stated that fertilizer application can cause the replacement of cations (H^+ and Al^{3+}) in the adsorption complex, thereby increasing the proportion of base cations. There is also class S1 land covering 605.67 ha with BS values ranging from 36.10% to 48.27%, found in land map units K1, K3, T3, and S1. According to Djaenuddin (2011), in general, soils that are optimal for durian growth and development have a base saturation above 35%.

The land suitability level based on soil base saturation (BS) for durian in Bumiaji District is dominated by class S2, covering an area of 6,248.95 ha, with BS categorized as medium to low, ranging from 18.89% to 35.97%. The highest BS value was found in land map unit K1 at 48.27%, while the lowest BS value was in land map unit K2 at 24.40%. This is possibly influenced by farmers' fertilization practices, which may lower BS values. Syamsiyah *et al*. (2023) stated that fertilizer application can cause the replacement of cations (H^+ and Al^{3+}) in the adsorption complex, thereby increasing the proportion of base cations. There is also class S1 land covering 605.67 ha with BS values ranging from 36.10% to 48.27%, found in land map units K1, K3, T3, and S1. According to Djaenuddin (2011), in general, soils that are optimal for durian growth and development have a base saturation above 35%.

Based on these results, the base saturation (BS) values in Bumiaji District fall within the S2–S1 classes (moderately suitable to highly suitable), indicating that several areas still require appropriate management and improvement. Assessment of BS is important because it serves as an indicator of soil fertility status, helps in controlling soil acidity, and reflects the balance of essential base nutrients in the soil (Supriyadi, 2009).

3.2.3. pH level

Soil pH is an indicator of chemical reactions that reflects the level of soil acidity or alkalinity. The pH value greatly influences the ability of plants to absorb nutrients. In general, nutrient absorption occurs optimally under neutral pH conditions. Soil microorganisms, including fungi, can develop optimally when soil pH is above 5.5. Conversely, if the pH is too low, microbial activity will decrease and plant growth will be disrupted. High soil acidity can also inhibit the absorption of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are required for plant growth (Gunawan *et al*., 2019).

The land suitability level based on soil pH for durian in Bumiaji District covers 508.30 ha, which has acidic pH values and falls into class S2, namely K3 (6.05), S1 (6.21), S3 (6.26), S2 (6.46), and K1 (6.63). Soils categorized as class S1 include T1 (5.27), T2 (5.74), T3 (5.31), H1 (5.36), H2 (5.72), and H3 (5.05), covering an area of 6,263.77 ha. Soils with very acidic to extremely acidic pH values fall into class S3, with land unit K2 having a pH of 4.05, covering 126.56 ha. Durian requires an optimal pH to absorb the nutrients needed for its growth. According to Djaenuddin (2011), in general, soils that are optimal for durian have soil acidity (pH) ranging from 5.5 to 6.5. Based on these findings, soil pH in the study area is generally classified as S2 (moderately suitable). Although several locations indicate potential S1 (highly suitable) conditions, nearly half of the area remains in the S2 category, suggesting the need for appropriate soil management and improvement measures to optimize durian growth.

Table 6. pH level

No	Land unit	pH	Category	Criteria	Total Are Width (ha)
1	K1	6.63	Neutral	S2 (moderately suitable)	167.10
2	K2	4.05	Strongly acidic	S3 (Marginally suitable)	126.56
3	K3	6.05	Sligthy acidic	S2 (moderately suitable)	82.55
4	T1	5.27	Acidic	S1 (Highly suitable)	1,114.32
5	T2	5.74	Sligthy acidic	S1 (Highly suitable)	497.49
6	T3	5.31	Acidic	S1 (Highly suitable)	229.95
7	H1	5.36	Acidic	S1 (Highly suitable)	790.02
8	H2	5.72	Sligthy acidic	S1 (Highly suitable)	1,938.99
9	H3	5.05	Acidic	S1 (Highly suitable)	1,693.00
10	S1	6.21	Sligthy acidic	S2 (moderately suitable)	126.07
11	S2	6.46	Sligthy acidic	S2 (moderately suitable)	68.69
12	S3	6.26	Sligthy acidic	S2 (moderately suitable)	19.88

Description: K: Garden; T: Dry land field; H: Forest; S: Rice field

Table 7. C - Organic

No	Land unit	C- Organic (%)	Category	Criteria	Total Are Width (ha)
1	K1	3.06	High	S1 (Highly suitable)	167.10
2	K2	2.37	Medium	S1 (Highly suitable)	126.56
3	K3	2.74	Medium	S1 (Highly suitable)	82.55
4	T1	1.75	Low	S1 (Highly suitable)	1,114.32
5	T2	1.75	Low	S1 (Highly suitable)	497.49
6	T3	1.87	Low	S1 (Highly suitable)	229.95
7	H1	4.70	High	S1 (Highly suitable)	790.02
8	H2	4.69	High	S1 (Highly suitable)	1,938.99
9	H3	3.40	High	S1 (Highly suitable)	1,693.00
10	S1	2.49	Medium	S1 (Highly suitable)	126.07
11	S2	2.15	Medium	S1 (Highly suitable)	68.69
12	S3	2.76	medium	S1 (Highly suitable)	19.88

Description: K: Garden; T: Dry land field; H: Forest; S: Rice field

3.2.4. C-Organic

The organic carbon content in soil is an important criterion in assessing land suitability, as organic C plays a crucial role in maintaining soil fertility, improving water retention, and providing essential nutrient support for plant growth. An optimal level of organic C reflects the soil's capacity to support sustainable agricultural productivity and can influence the overall sustainability of the soil ecosystem (Fromherz, 2012). The land suitability level based on soil organic C for durian in Bumiaji District covers 6,854.62 ha, with organic C criteria classified into class S1. The organic C values are K1 (3.06), K2 (2.37), K3 (2.74), T1 (1.75), T2 (1.75), T3 (1.87), H1 (4.70), H2 (4.69), H3 (3.40), S1 (2.49), S2 (2.15), and S3 (2.76). In general, soils that are optimal for durian cultivation have an organic C suitability level of more than 1.2%.

Based on these results, the organic carbon content in Bumiaji District is classified as S1 (highly suitable), indicating favorable conditions for durian cultivation. However, continuous soil conservation and proper management practices are required to maintain organic C levels. Adequate organic carbon contributes to improved cation exchange capacity, better soil structure and water-holding capacity, enhanced soil fertility, and increased fruit productivity and quality (Abel *et al*., 2021).

3.3. Improvement Methods

One effective approach to improving base saturation (BS), particularly in areas with relatively high soil acidity, is through liming. The application of dolomite [$CaMg(CO_3)_2$] is highly recommended because, in addition to its strong neutralizing capacity, it contains relatively high concentrations of calcium (Ca) and magnesium (Mg). Compared to other liming materials, dolomite provides dual benefits by correcting soil acidity and enriching essential base cations.

Fitria *et al*. (2024) reported that liming aims to increase soil pH from acidic or very acidic conditions toward a more neutral range, while simultaneously reducing aluminum (Al) toxicity. Furthermore, dolomite application effectively increases Ca and Mg availability in the soil, thereby contributing to higher base saturation values.

Soils with low pH generally exhibit limited nutrient availability and inhibited organic matter decomposition. Soil pH also plays a crucial role in regulating microbial activity, as it reflects the presence of toxic elements and influences nutrient uptake efficiency. Therefore, soil acidity constraints can be mitigated through liming practices, particularly using dolomite. Hartati *et al*. (2018) emphasized that dolomite application not only increases soil pH but also enhances microbial activity and reduces exchangeable aluminum (Al-exc), which is harmful to plant growth.

In addition to liming, organic matter application is also effective in improving acidic soil conditions. Indriyanti *et al*. (2023) demonstrated that the incorporation of organic materials derived from cattle and poultry manure, rice straw, and legume residues at a rate of 15 t/ha significantly reduced exchangeable Al and increased soil pH. Field observations further indicate that some durian trees exhibit tolerance to slightly acidic soils. According to Lubis *et al*. (2024), plants can adapt to environmental conditions and producing offspring that inherit favorable adaptive traits.

4. CONCLUSION

The land suitability evaluation indicates that most areas in Bumiaji District are classified as highly suitable (S1) for durian cultivation based on cation exchange capacity (CEC) and organic carbon content. However, base saturation (BS) in areas K2, T1, T2, H1, H2, H3, S2, and S3, as well as soil pH in areas K1, K2, K3, S1, S2, and S3, range from moderately suitable (S2) to marginally suitable (S3) and represent the main limiting factors for durian production. These limitations highlight the need for appropriate soil management practices, particularly liming with dolomite and the application of organic matter, to improve soil pH and base saturation. Improvement of these soil chemical properties is expected to enhance durian productivity in an optimal and sustainable manner. Furthermore, several parts of Bumiaji District are characterized as agroforestry areas integrated with livestock farming. This condition provides opportunities for farmers to utilize animal manure as organic fertilizer, which can contribute to improving base saturation and correcting soil acidity.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
BDS	✓	✓				✓		✓	✓	✓				
Pur				✓						✓		✓		
Mar				✓						✓		✓		

C: Conceptualization	Fo: Formal Analysis	O: Writing - Original Draft	Fu: Funding Acquisition
M: Methodology	I: Investigation	E: Writing - Review & Editing	P: Project Administration
So: Software	D: Data Curation	Vi: Visualization	
Va: Validation	R: Resources	Su: Supervision	

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