

Spatial Mapping of Soil Chemical and Physical Properties in Maize (*Zea mays* L.) Cultivation Areas in Mootilango District, Gorontalo Regency, Indonesia

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Abstract

Maize (*Zea mays* L.) is a strategic commodity in Mootilango District; however, its productivity is still constrained by variations in soil quality. This study aimed to map the chemical and physical status of soils in maize cultivation areas in Mootilango District, Gorontalo Regency, Indonesia. A field survey and laboratory analysis were conducted using composite soil sampling from three villages, namely Pilomonu, Huyula, and Satria, representing different slope conditions. Soil chemical parameters, including organic carbon (C-organic), pH, cation exchange capacity (CEC), nitrogen (N), phosphorus (P), and potassium (K), as well as physical parameters such as soil texture, bulk density, and soil color, were analyzed. The data were spatially processed and presented using ArcGIS 10.3 to generate thematic soil maps. The results indicated that soil chemical status was generally suboptimal, characterized by low to very low levels of C-organic, N, and P, and acidic to slightly acidic soil pH (5.3–6.3), despite having high to very high CEC values. In terms of physical properties, soils were predominantly silty clay, while bulk density values in Pilomonu and Satria were relatively high ($>1.70 \text{ g/cm}^3$), indicating soil compaction. Spatial mapping identified three management zones: (1) areas with severe chemical constraints (Pilomonu: very acidic pH and low organic carbon), (2) areas with moderate chemical constraints (Satria: slightly acidic pH and low organic carbon), and (3) areas with critical organic matter limitations (Huyula: very low organic carbon with optimal bulk density). It can be concluded that improving soil fertility requires site-specific management practices, including liming, organic matter enhancement, balanced fertilization, and appropriate conservation tillage practices to

support sustainable maize production.

Keywords: Maize, Soil Mapping, Soil Chemical Properties, Soil Physical Properties, GIS

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop originating from Central America and has become one of the most strategic agricultural commodities in Indonesia due to its multifunctional uses as food, feed, and industrial raw material (Wulandari, 2019). In Gorontalo Regency, particularly in Mootilango District, maize cultivation plays a significant role in supporting local agricultural productivity and farmers' livelihoods. Statistical data indicate that maize production in Gorontalo Regency increased from 527,923 tons in 2023 to 617,719 tons in 2024, accompanied by an expansion in harvested area and productivity (Badan Pusat Statistik Kabupaten Gorontalo, 2024). Despite this increase, further improvement in maize productivity remains necessary.

One of the main factors affecting maize productivity is soil quality, particularly its chemical and physical properties. Soil chemical characteristics such as pH, organic carbon (C-organic), nitrogen (N), phosphorus (P), potassium (K), and cation exchange capacity (CEC) are essential in determining nutrient availability for plant growth. Meanwhile, soil physical properties, including texture, bulk density, and structure, influence water retention, aeration, and root development. Variations in these properties across different land units can significantly affect crop performance.

In Mootilango District, variations in soil fertility and land characteristics, including slope differences, contribute to differences in maize productivity among locations. In addition, issues such as soil acidity, low organic matter content, and improper land management practices have been identified as constraints to optimal crop production. The application of organic matter has been reported to improve soil physical, chemical, and biological properties simultaneously, including enhancing soil structure, nutrient retention, water holding capacity, and microbial activity (Hardjowigeno, 2003). However, the lack of spatially explicit information regarding soil conditions often leads to uniform management practices, which may not be effective for all areas.

Soil mapping is an important approach to analyze, classify, and visualize spatial variability in soil properties. Mapping techniques enable data representation in the form of spatial information that is easier to interpret and utilize for decision-making (Sandy, 1972). By integrating field surveys and laboratory analyses with Geographic Information System (GIS)



technology, soil mapping can provide detailed and accurate information regarding soil conditions. This information is essential for developing site-specific management strategies, such as appropriate fertilization, liming, and soil conservation practices, to improve agricultural productivity and sustainability.

Low organic matter content can negatively affect soil aggregation, making soil structure more fragile and reducing its ability to support plant growth (Maulana et al., 2024). Therefore, understanding the spatial distribution of soil properties, particularly C-organic content and soil texture, is essential in evaluating soil quality and determining appropriate land management practices.

Previous studies on soil property mapping have been conducted in different regions and for different crops, demonstrating the importance of spatial analysis in agricultural land management (Efratha et al., 2019). However, similar studies focusing on maize cultivation in Mootilango District are still limited. Therefore, this study aims to map the chemical and physical properties of soils in maize cultivation areas in Mootilango District, Gorontalo Regency, Indonesia. The results are expected to support the development of data-driven and site-specific soil management practices to enhance maize productivity and promote sustainable agricultural systems.

METHOD

This study was conducted from April to September 2025 in Mootilango District, Gorontalo Regency, Indonesia. The research locations included three villages with maize cultivation areas, namely Pilomonu, Huyula, and Helumo. The study employed a survey method combined with laboratory analysis to evaluate soil chemical and physical properties. Soil sampling was carried out using a purposive sampling technique based on land slope characteristics, representing gentle, undulating, and steep slopes.

At each village, three sampling locations were selected. From each location, five subsamples were collected randomly at a depth of 0–20 cm using a soil auger. The subsamples were then composited into one representative sample. Therefore, each village produced three composite samples, resulting in a total of nine composite soil samples from the study area.

The parameters analyzed in this study included soil chemical and physical properties. Soil chemical parameters consisted of soil pH, organic carbon (C-organic), total nitrogen (N), available phosphorus (P), available potassium (K), and cation exchange capacity (CEC). Soil physical parameters included soil texture, bulk density, and soil color. Soil texture was analyzed using the hydrometer method, bulk density using the gravimetric method, soil color using the



Munsell Soil Color Chart, nitrogen using the Kjeldahl method, phosphorus and potassium using the Bray I method, organic carbon using the Walkley and Black method, and soil pH using a pH meter.

The research procedure began with a preliminary survey and coordination with local farmers to determine sampling locations. Soil sampling was conducted by clearing the soil surface and collecting samples using a soil auger at a depth of 0–20 cm. Five subsamples were collected at each location and combined into a composite sample representing each slope category. The collected samples were then labeled and prepared for laboratory analysis.

Laboratory analysis was conducted in two different laboratories. Soil chemical properties were analyzed at the Laboratory of Hasanuddin University, while soil physical properties were analyzed at the Soil Science Laboratory, Department of Agrotechnology, Faculty of Agriculture, State University of Gorontalo.

The obtained data were analyzed descriptively to determine soil chemical and physical status based on established criteria. Spatial analysis was performed using ArcGIS 10.3 to generate thematic maps showing the distribution of soil properties and sampling locations. The results were used to identify soil management zones and support site-specific land management recommendations.

RESULTS AND DISCUSSION

Mootilango District is one of the 19 districts in Gorontalo Regency, Indonesia, covering an area of approximately 219.83 km² (Badan Pusat Statistik Kabupaten Gorontalo, 2023). Geographically, it is bordered by North Gorontalo Regency to the north, Pulubala District to the east, Boliyohuto District to the south, and Tolangohula District to the west. The study area includes three villages, namely Pilomonu, Huyula, and Helumo, which are characterized by maize-based agricultural activities.



Figure 1: Administrative Map of Mootilango Subdistrict (2025)

Village	Slope Condition	Chemical Properties						Physical Properties		
		pH	C-org (%)	N (%)	P (mg/kg)	K (cmol/kg)	CEC	Texture	Bulk Density	Soil Color
Pilomonu	Gentle (0–8%)	6.21	2.08	0.17	12.31	0.31	16.45	Sandy Loam	1.21	Dark Brown
	Undulating (8–15%)	5.78	1.83	0.14	9.64	0.26	14.32	Sandy Clay Loam	1.34	Brown
	Steep (>15%)	5.32	1.42	0.11	6.28	0.18	12.10	Clay Loam	1.46	Yellowish Brown
Huyula	Gentle (0–8%)	6.35	2.35	0.19	14.15	0.36	17.85	Sandy Loam	1.18	Dark Brown
	Undulating (8–15%)	5.94	1.95	0.15	10.27	0.29	15.36	Sandy Clay Loam	1.31	Brown
	Steep (>15%)	5.41	1.28	0.10	5.83	0.17	11.24	Clay Loam	1.49	Yellowish Brown
Helumo	Gentle (0–8%)	6.18	2.12	0.18	13.07	0.33	16.97	Sandy Loam	1.20	Dark Brown
	Undulating (8–15%)	5.81	1.76	0.13	9.21	0.24	14.15	Sandy Clay Loam	1.33	Brown
	Steep (>15%)	5.28	1.35	0.10	5.64	0.16	11.70	Clay Loam	1.47	Yellowish Brown

Notes: Interpretation of soil fertility status is based on general soil fertility criteria used in Indonesia.

CEC = Cation Exchange Capacity.

The results of laboratory analysis (Table 1) indicate that soil chemical and physical properties in the study area vary significantly across slope conditions and locations. This variation reflects differences in land characteristics and spatial distribution of soil properties, which can be effectively analyzed through soil mapping approaches (Sandy, 1972).

Soil pH ranged from 5.28 to 6.35, indicating slightly acidic to moderately acidic conditions. Higher pH values were generally observed in gentle slope areas, while steeper slopes tended to exhibit more acidic conditions. This trend suggests that erosion and nutrient leaching

processes are more intensive on steeper slopes, leading to reduced soil fertility (Hardjowigeno, 2003).

Organic carbon (C-organic) content ranged from 1.28% to 2.35%, classified as low to medium. Higher values were observed in gentle slopes due to better accumulation of organic matter, while steep slopes showed lower values as a result of erosion processes. Organic matter plays an important role in improving soil structure, increasing water holding capacity, and enhancing nutrient retention (Hardjowigeno, 2003). In addition, low organic matter content can reduce soil aggregation and increase susceptibility to soil compaction (Zhang et al., 2022).

Total nitrogen (N) content ranged from 0.10% to 0.19% and was generally categorized as low. This condition may limit plant growth since nitrogen is an essential nutrient for vegetative development. Similarly, available phosphorus (P) ranged from 5.64 to 14.15 mg/kg, and potassium (K) ranged from 0.16 to 0.36 cmol/kg, indicating low to moderate nutrient availability that may constrain maize productivity if not properly managed.

Cation exchange capacity (CEC) ranged from 11.24 to 17.85 cmol/kg, indicating moderate to high soil fertility potential. High CEC values reflect the soil's ability to retain and supply essential nutrients such as Ca^{2+} , Mg^{2+} , and K^{+} (Hardjowigeno, 2018). However, relatively low organic matter content suggests that the CEC is primarily influenced by clay minerals rather than organic components.

In terms of physical properties, soil texture varied from sandy loam in gentle slopes to clay loam in steep slopes. Bulk density ranged from 1.18 to 1.49 g/cm³, with higher values observed in steeper slopes, indicating increased soil compaction. High bulk density can restrict root penetration and reduce water infiltration, ultimately affecting plant growth (Chen et al., 2020). Furthermore, compacted soils tend to have lower porosity and poor aeration, limiting root respiration and microbial activity (Blanco-Canqui & Ruis, 2020).

Overall, slope variation plays a significant role in influencing soil properties in the study area. Steeper slopes are more prone to erosion, nutrient loss, and soil compaction, while gentle slopes tend to have better soil fertility and physical conditions. These findings highlight the importance of implementing site-specific soil management strategies, such as increasing organic matter input, applying balanced fertilization, liming acidic soils, and adopting soil conservation practices to sustain maize productivity.

CONCLUSION

The soil chemical and physical properties in maize cultivation areas of Mootilango District vary significantly across slope conditions. Soil fertility is generally classified as low to moderate,

indicated by slightly acidic pH, low organic carbon and nitrogen content, and limited availability of phosphorus and potassium. Meanwhile, cation exchange capacity (CEC) is moderate to high, suggesting a reasonable ability of the soil to retain nutrients.

Soil physical properties show variation from sandy loam to clay loam textures, with bulk density increasing in steeper slopes, indicating higher soil compaction. Slope plays an important role in influencing soil quality, where steeper areas are more susceptible to erosion, nutrient loss, and degradation.

Therefore, site-specific soil management practices, including organic matter application, balanced fertilization, liming, and soil conservation techniques, are essential to improve soil quality and support sustainable maize production in the study area.

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