

Chemical and Physical Characteristics of Soils under Maize (*Zea mays* L.) Cultivation in Pulubala District, Gorontalo Regency

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Abstract

*Soil fertility is a key factor influencing maize productivity, particularly in intensive agricultural areas. This study aimed to evaluate the chemical and physical soil properties of maize (*Zea mays* L.) fields in Pulubala District, Gorontalo Regency, Indonesia. The study was conducted from April to May 2025 in three maize-growing villages, namely Mulyonegoro, Puncak, and Molalahu. Soil samples were collected using a diagonal sampling technique at a depth of 0–30 cm. Soil physical properties analyzed included texture, bulk density, and water content, while chemical properties comprised soil pH, organic carbon, total nitrogen, available phosphorus (Olsen P_2O_5), exchangeable potassium, cation exchange capacity, and base saturation. The results indicated that soils in the study area were generally slightly acidic, with low organic carbon, low available phosphorus, and low base saturation, despite moderate nitrogen and high potassium availability. These conditions indicate that low organic matter content and phosphorus deficiency are the main limiting factors for soil fertility in the maize fields of Pulubala District. Integrated soil management practices, including organic matter application and balanced fertilization, are required to improve soil quality and support sustainable maize production.*

Keywords: soil fertility; maize; chemical properties; physical properties; Pulubala District

INTRODUCTION

Soil is a fundamental natural resource that functions as a growing medium and a provider of essential nutrients for crop production. Soil is formed through long-term weathering processes influenced by parent material, organisms, climate, and time, resulting in a dynamic system



composed of minerals, organic matter, water, and air (Mujiyo et al., 2018). In agricultural systems, soil fertility is determined by the integration of physical, chemical, and biological properties, where imbalance among these components may restrict nutrient availability and plant growth (Wahab et al., 2022).

In maize cultivation, soil physical properties such as texture and water-holding capacity influence root development and soil aeration, while chemical properties including soil pH, cation exchange capacity (CEC), and the availability of essential nutrients play a critical role in nutrient uptake and crop productivity (Delsiyanti et al., 2016; Putri et al., 2019). Unfavorable soil chemical conditions, particularly acidic soil reactions, may limit nutrient absorption even when nutrients are present in sufficient amounts (Armita et al., 2022). Soil biological activity also contributes to organic matter decomposition and nutrient cycling, thereby supporting soil fertility sustainability (Harista and Soemarno, 2017).

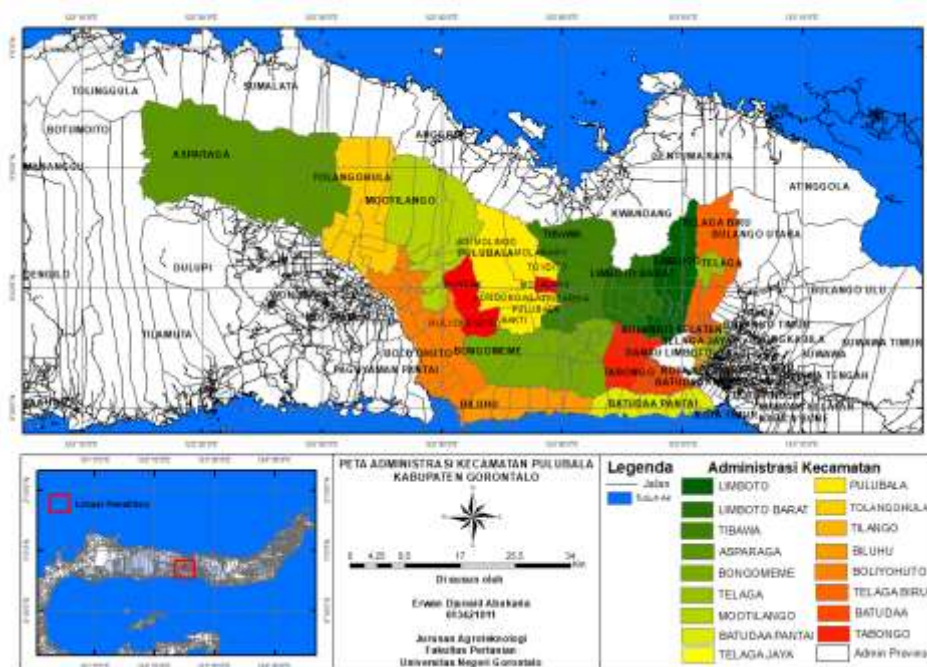
Although national maize production in Indonesia increased from 12.93 million tons in 2020 to 15.21 million tons in 2024, productivity remains fluctuative due to variations in climate, harvested area, adoption of improved varieties, and soil fertility conditions (Gunawan et al., 2025). Gorontalo Province is one of Indonesia's major maize production centers, with a planting area of approximately 400,000 ha, of which about 100,000 ha are located in Gorontalo Regency (Usman et al., 2023). However, previous studies have reported several soil fertility constraints in this region, including low organic carbon content, imbalance of macro- and micronutrients, and topographic effects on maize growth and yield (Abdullah et al., 2023; Hasyyati et al., 2023; Husain et al., 2022). Spatial land suitability analysis further indicates that parts of Gorontalo are classified as marginally suitable to unsuitable due to limiting factors such as acidic soil pH, low permeability, and high erosion risk (Bagu, 2025).

Pulubala District, located in Gorontalo Regency, covers an area of approximately 240.57 km² consisting of 11 villages and is characterized by heterogeneous land conditions dominated by sloping areas, with maize as the primary agricultural commodity (BPS, 2020; Nani and Si, 2018). Despite its strategic role in maize production, comprehensive and site-specific information regarding soil physical and chemical fertility status in this area remains limited. Therefore, this study aims to evaluate the physical and chemical soil fertility status of maize-growing land in Pulubala District to identify key limiting factors affecting productivity. The findings are expected to provide scientific evidence to support the development of effective and sustainable soil management strategies for improving maize production in the region.



METHOD

This study was conducted from April to May 2025 in Pulubala District, Gorontalo Regency, Indonesia. The research area consisted of three maize-growing villages, namely Mulyonegoro, Puncak, and Molalahu. The geographical coordinates of the sampling locations were 0°37'49.95"N, 122°42'57.60"E for Mulyonegoro, 0°38'59.46"N, 122°43'3.78"E for Puncak, and 0°39'59.78"N, 122°47'46.91"E for Molalahu. These locations represent maize cultivation areas with varying land and topographic conditions. A location map was used to illustrate the distribution of sampling sites within Pulubala District.



The research employed a descriptive quantitative approach to evaluate the physical and chemical fertility status of soils under maize cultivation. Soil sampling was carried out using a diagonal sampling technique to represent spatial variability within each field. Samples were collected at a depth of 0–30 cm. Undisturbed soil samples were obtained using a ring sampler for physical property analysis, while disturbed soil samples were collected using a soil auger for chemical analysis.

Soil chemical analyses were conducted at the Soil Chemistry and Fertility Laboratory, Hasanuddin University, Makassar, while soil physical analyses were performed at the Soil Science Laboratory, Department of Agrotechnology, Faculty of Agriculture, Universitas Negeri Gorontalo. Prior to laboratory analysis, soil samples were air-dried, crushed, and sieved through a 2 mm mesh. Soil physical properties analyzed included soil texture determined by the hydrometer

method, soil color using the Munsell Soil Color Chart, gravimetric water content, and bulk density. Chemical soil properties analyzed comprised soil pH measured electrometrically, organic carbon content determined by the Walkley and Black method, total nitrogen analyzed using the Kjeldahl method, available phosphorus measured using the Olsen P_2O_5 method, available potassium extracted with NH_4OAc (pH 7.0), as well as cation exchange capacity and base saturation determined using NH_4OAc extraction at pH 7.0.

Data were analyzed descriptively and interpreted based on soil fertility criteria to evaluate soil conditions and identify major limiting factors.

RESULTS AND DISCUSSION

The results of laboratory analysis showed variations in soil physical and chemical properties among maize fields in Pulubala District, Gorontalo. Differences in land characteristics, management practices, and inherent soil conditions contributed to the observed variability. The physical properties of the soils are presented in Table 1, while the chemical properties are summarized in Table 2.

Table 1. Physical soil properties of maize fields in Pulubala District

Parameter	Mulyonegoro	Puncak	Molalahu	Criteria / Reference
Texture	Loam	Clay loam	Sandy loam	USDA Soil Texture Triangle
Bulk density ($g\ cm^{-3}$)	1.32	1.35	1.28	Moderate (Delsiyanti et al., 2016)
Water content (%)	28.41	26.87	29.15	Moderate

Table 2. Chemical soil properties of maize fields in Pulubala District

Parameter	Mulyonegoro	Puncak	Molalahu	Fertility status / Reference
pH (H_2O)	6.0	6.1	6.0	Slightly acidic (Armita et al., 2022)
C-organic (%)	1.42	1.88	1.63	Low (Harista & Soemarno, 2017)
N-total (%)	0.16	0.21	0.18	Moderate (Putri et al., 2019)
Available P (Olsen P_2O_5 , $mg\ kg^{-1}$)	9.49	10.17	9.88	Low (Husain et al., 2022)
Exchangeable K ($cmol\ kg^{-1}$)	0.12	0.16	0.14	High (Wahab et al., 2022)

Parameter	Mulyonegoro	Puncak	Molalahu	Fertility status / Reference
CEC (cmol kg ⁻¹)	17.44	19.69	18.12	Moderate
Base saturation (%)	28	30	29	Low (Delsiyanti et al., 2016)

Soil Chemical Properties of Maize Fields in Pulubala District

The soil pH across all observation sites ranged from 6.0 to 6.1, indicating slightly acidic conditions. This pH range is generally suitable for maize growth; however, it may limit phosphorus availability due to fixation by aluminum and iron compounds under acidic conditions (Armita et al., 2022). Similar soil reactions have been widely reported in maize-growing areas of Gorontalo and are considered a major constraint to nutrient use efficiency (Abdullah et al., 2023).

Soil organic carbon content was classified as low at all sites, ranging from 1.42 to 1.88%. Low C-organic levels indicate limited organic matter inputs and continuous reliance on inorganic fertilizers. This condition adversely affects soil aggregation, microbial activity, and nutrient retention capacity, ultimately reducing soil fertility sustainability (Harista and Soemarno, 2017). Previous studies have reported that intensive maize cultivation without organic amendments accelerates soil organic matter depletion (Hasyati et al., 2023).

Total nitrogen content ranged from 0.16 to 0.21% and was categorized as moderate. This suggests that nitrogen availability was sufficient to support vegetative growth of maize. Nevertheless, moderate nitrogen levels may decline rapidly due to crop uptake and leaching if not supported by balanced fertilization practices (Putri et al., 2019).

Available phosphorus (Olsen P₂O₅) content was consistently low across all locations, with values ranging from 9.49 to 10.17 mg kg⁻¹. Low phosphorus availability is closely associated with soil acidity and phosphorus fixation processes. Phosphorus deficiency can restrict root development and energy transfer in maize plants, resulting in reduced yield potential (Husain et al., 2022). This finding aligns with the spatial analysis reported by Bagu (2025), which identified phosphorus limitation as a dominant constraint in Gorontalo agricultural land.

Exchangeable potassium content was classified as high at all observation sites. High potassium availability plays a crucial role in enzyme activation, stomatal regulation, and carbohydrate translocation in maize plants. The relatively high potassium status may be attributed to the mineralogical composition of the soil and moderate cation exchange capacity, which reduces potassium losses through leaching (Wahab et al., 2022).

Cation exchange capacity values ranged from 17.44 to 19.69 cmol kg⁻¹, indicating moderate nutrient retention capacity. However, base saturation values were low (28–30%), suggesting dominance of acidic cations in the soil exchange complex. Low base saturation implies



limited availability of essential base cations such as calcium and magnesium, which may constrain nutrient balance and root development (Delsiyanti et al., 2016).

Soil Fertility Constraints and Management Implications

Overall, the main soil fertility constraints in maize fields of Pulubala District include low organic carbon content, low available phosphorus, and low base saturation, despite moderate nitrogen and high potassium availability. These conditions indicate that soil fertility management should prioritize organic matter enrichment, balanced fertilization, and pH management to enhance nutrient availability and improve soil quality.

The application of organic amendments such as compost or manure is expected to increase soil organic carbon, improve cation exchange capacity, and enhance base saturation. Such integrated soil management strategies are essential to support sustainable maize production and improve land productivity in Pulubala District under varying land conditions.

CONCLUSION

This study demonstrated that soil fertility conditions of maize fields in Pulubala District, Gorontalo, varied among locations but generally exhibited similar constraints. The soils were characterized by slightly acidic pH, low organic carbon content, low available phosphorus, and low base saturation, despite moderate total nitrogen and high exchangeable potassium levels.

These conditions indicate that soil chemical limitations remain a major factor influencing maize productivity in the study area. Improving soil organic matter inputs and phosphorus availability through integrated soil management practices is essential to enhance soil fertility and support sustainable maize production in Pulubala District.

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