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Gilgai microtopography of soil from carbonate rocks

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Abstract. Gilgai microtopography is a characteristic topography of soils that develops from carbonate rocks influenced by smectite clay minerals. The process of forming a gilgai can inhibit the development of plant growth and soil stability. Soil genesis is an interesting topic to study, especially concerning how moving clay forms a gilgai microtopography. The objective was to study forming a gilgai microtopography formed from the parent material of carbonate rock in Mangarabombang District, Takalar Regency. The methods used are survey methods, analysis of soil physical characteristics and soil chemistry, and soil mineral. The results showed an increase in clayeyness at the top horizon in line with decreasing permeability on the top horizon and inversely proportional to soil porosity. The cation exchange capacity is higher at the top horizon, which indicates an increase in clay content. The mineral content of clay is nontronite as a member of the smectite group. Nontronite mineral formation subsidized by calcium and magnesium cations from carbonate rocks. This mineral absorbed more water and caused the saturation conditions triggering lateral pressure and forming a gilgai micro-topography.

1. Introduction

Vertisols are predominantly formed from basaltic igneous rock, carbonate rock, gneiss, and alluvium [1] in a dry climate. The high nutrient content of calcium and magnesium from the parent material forms clay minerals of at least 30% in the soil [2]. The predominance of the smectite clay minerals formed greatly affects soil moisture, has hard and crack properties when dry, and is very plastic when wet [3, 4, 5]. The repeated dry and wet processes create a special microtopographic known as gilgai [6,7]. This micro-topography can inhibit plant roots so that it can reduce land productivity [8].

Gilgai-microtopography on Vertisols soil surface is mounds or micro knolls and small depressions [9]. The micro-topography characteristic has not been widely studied, and there is little information regarding the formation process. Likewise, alternative information to anticipate the formation process can inhibit plant growth and disturb soil stability [10, 11, 12]. Research related to the characteristic of gilgai soil is very necessary for land management. Soil characteristics can provide information regarding the soil's physical and chemical properties and information on its use. The objective was to study forming a gilgai microtopography formed from the parent material of carbonate rock in Mangarabombang District, Takalar Regency.

2. Materials and methods

The research area was located in Mangara Bombang District, Takalar Regency, South Sulawesi Province, Indonesia, with a coordinate's location in 119°25'53.04"E to 119°27'7.6"E and 5°34'6.79'S to 5°34'37.93"S (figure 1). Six soil profiles and samples for physical and chemical analysis were taken from the soil developed from the Tonasa Formation's carbonate rock (Temt). Mean rainfall for ten years is 1,853 mm/year (2010-2019) (figure 2). Soil analysis using BPT [13] procedure for pH, C-Organic, cation exchange capacity (CEC), bulk density (BD), particle density (PD), porosity, and permeability. X-ray Diffractometer (XRD) for clay mineral identification [14].

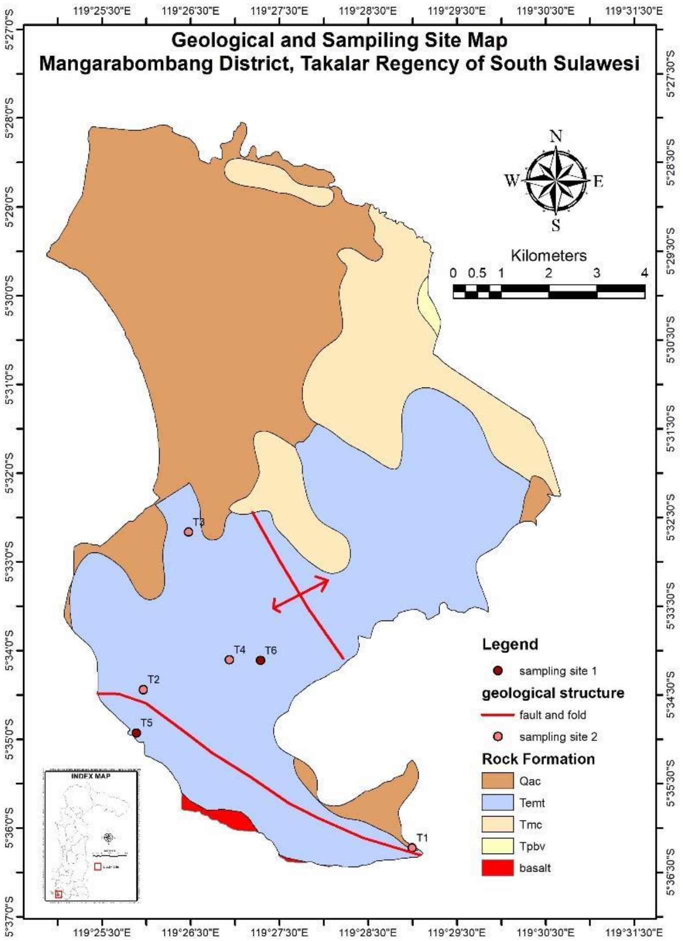

Figure 1. Geological and sampling site map.

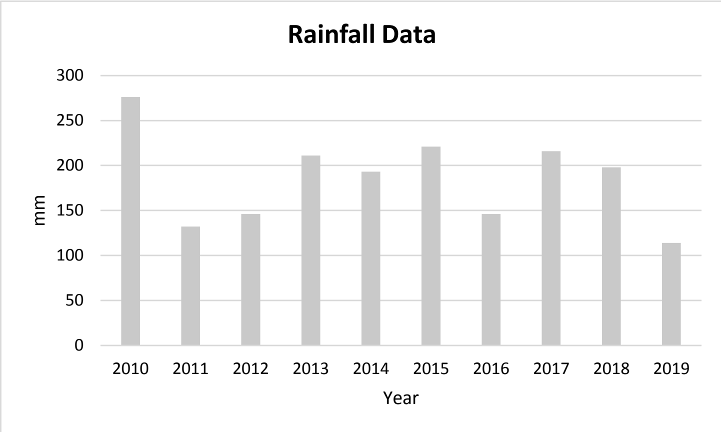

Figure 2. Rainfall data of Mangarabombang District in 2010-2019.

3. Results

The analysis of the soil's physical and chemical characteristics showed that the soil pH value was slightly acidic (6.15-6.58), and the soil C-organic was in the medium to high criteria (2.29%-3.60%). The soil has a clay loam texture, slightly sticky consistency, and blocky structure. The average C-organic value was in line with the decrease in soil bulk density (figure 3). This shows the effect of soil organic matter content on decreasing soil bulk density, and it is directly proportional to the increase in soil porosity (figure 4). The soil CEC is higher at the top horizon (22-26 cmol/kg) than in the sub horizon (18-20cmol/kg), which indicates an increase in clay content.

Soil mineral dominated by nontronite mineral as a member of the smectite group (figure 5). Nontronite mineral formation subsidized by calcium and magnesium cations from carbonate rocks. These minerals can absorb water and reduce permeability. Soil permeability is in the slow to moderate category [15], with a value of 2.06 cm/hour to 2.56 cm/hour, and is inversely proportional to the value of soil porosity which is in the very high category [16] with a value of 50.4% to 56.5%. This shows that the soil tends to be in saturated condition during the rainy season.

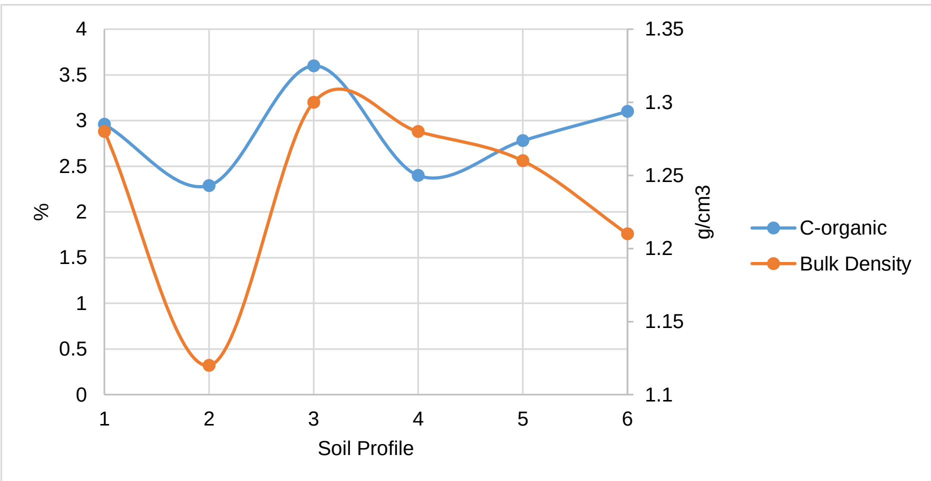

Figure 3. Relationship between C-organic content and bulk density of soil.

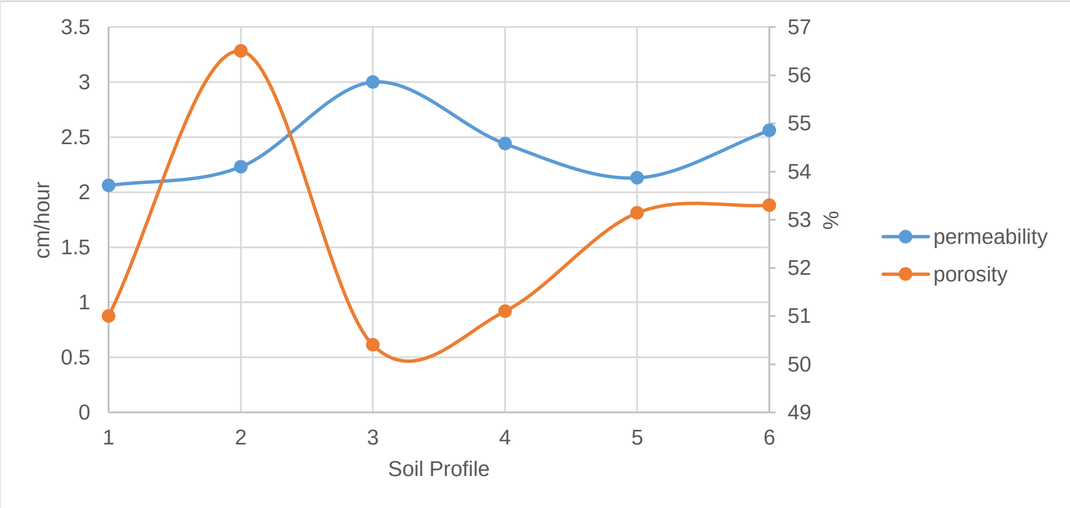

Figure 4. Relationship between permeability with the porosity of the soil.

The appearance of gilgai micro-topography can form peaks of mounds with a height of up to 50 cm and a width of up to 1 meter. Gilgai formed in Laikang Village has a higher mounds peak than in the Punaga Village (figure 5). The relatively plain morphology in Laikang Village affects the formation of gilgai with greater lateral force. Gilgai in Punaga Village still contains parent rock fragment >2mm-4mm in size with a percentage of 30%, while Laikang Village dominates with soil fraction and only about 10% of the parent rock fragments (figure 6).

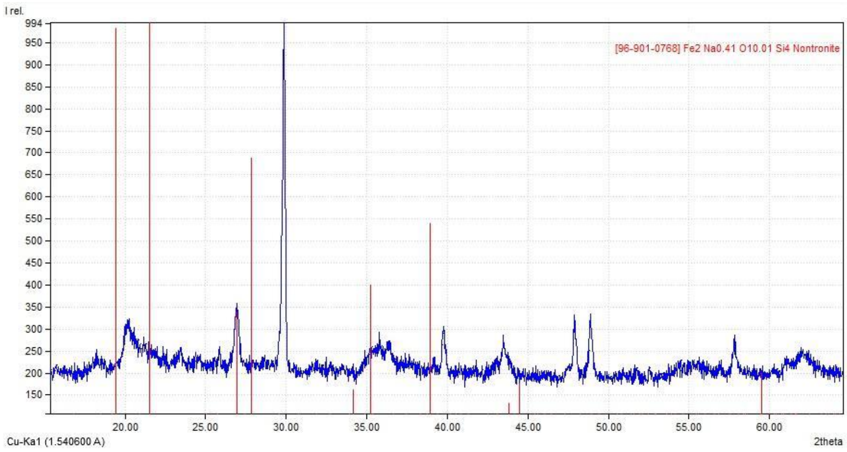

Figure 5. XRD of nontronite minerals of the smectite group.

Figure 6. Gilgai micro-topography in Punaga Village (A) with mound has high 6 cm (B), and Laikang Village (C) with mound has high 11cm (D).

4. Discussion

Incorporating c-organic soil with an average clay fraction content of 31.2% increased the soil to bind water with a high porosity value. Combining c-organic and clay fractions have increased soil water content by around 33% to 44% [17]. Differences in water content between the top horizon and sub-horizon as the factor that influenced the gilgai microtopography processes.

The increased soil porosity is not in line with the soil permeability, so that soil saturation increases. The decrease in the soil's ability to pass water is due to the increase in soil smectite mineral content, which has a large surface and interlayer crystal to absorb large amounts of water [18]. The binding of water by smectite minerals increases soil volume and triggers lateral soil expansion [19].

The soil expansion process results in a lateral collision by two soil masses of different volumes and causing a mound on the soil. This is similar to the process of the Earth's plate convergent force (knight). The process of lateral force collisions can occur where the soil is seasonally wet and dry [20] and contains rock fragments in it on plain morphology with slopes <10% [20, 21].

Soils derived from carbonate rocks tend to form mounds [20, 22] because they tend to form a slightly sticky consistency and blocky structure. This condition can trigger higher lateral soil pressure and form mounds in the form of gilgai micro-topography. Land management and drainage arrangements are needed in utilizing the soil with gilgai micro-topography.

5. Conclusion

Soil development from carbonate rock parent material has a sticky and blocky structure. It is caused by the increase in smectite mineral content of at least 30% and moderate C-organic content, increasing soil water absorption and decreasing soil permeability. Soil saturation conditions triggered lateral pressure and formed a gilgai micro-topography.

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