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EVALUATION OF COLE VALUE, ACIDITY AND TEXTURE OF ULTISOLS AND INCEPTISOLS IN SIBORONG-BORONG DISTRICT

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ABSTRACT

Identification of capacity of linearity and extensibility of clay, soil acidicity and texture of agricultural soils is very important because these properties are related to the estimation of soil fertility potential. This study aims to know the distribution of values of COLE, soil acidicity and texture in Ultisols and Inceptisols from Siborong-Borong district, North Tapanuli Regency, North Sumatra Province. This research was conducted by using descriptive quantitative method and soil sampling are taken by random sampling technique at 0 - 20 cm and 20 - 40 cm dept (32 samples). Parameters were analyzed consist of soil COLE value, soil acidicity and texture. The results of the analysis of Ultisol and Inceptisol soil at a depth of 20 and 40 cm show that the COLE value is classified as low to medium, ranging from 0.02 to 0.06. Soil texture are loam, sandy loam and clayey sand with a clay content of < 15%. The soil pH (acidity) value is 4.75-5.91 with the criteria of acidic and slightly acidic.

Key words: Acidicity COLE, Inceptisols, Texture, Ultisols.

INTRODUCTION

Ultisols are old soils whose parent material was leached during the soil formation process, causing the top layer to become very acidic (Junedi, 2010). Ultisols are generally brownish-yellow to red in color. Soil color is generally influenced by several factors, including organic matter, which causes a dark or black color; light-fraction primary minerals such as quartz and plagioclase, which give a grayish-white color; and iron oxides such as goethite and hematite, which give a brownish to red color (Schwertmann and Taylor, 1989). Ultisols can develop from a variety of parent materials, from acidic to alkaline; however, most parent materials are acidic sedimentary rocks (Syahputra *et al*., 2015). Inceptisol (inceptum or beginning) can be called young soil because its formation is relatively fast as a result of weathering of parent material (Damanik *et al*., 2010) Inceptisol has a characteristic horizon in the form of a cambic horizon, most Inceptisols show a texture of sandy clay loam, dusty clay loam and sandy clay with soil color tending to be dark. Inceptisol has a sandy clay loam texture with a crumb structure, relatively moderate nutrient content and reserves (Rajamuddin and Sanusi, 2014). The characteristics of Inceptisol soil have a rather thick soil solum of 1-2 meters, crumbly soil structure with loose consistency, pH 5.0 to 7.0, fairly high organic matter (10% to 31%), moderate to high nutrient content and moderate to high soil productivity (Utami dan Handayani, 2003).

Soil texture is one of the soil properties that significantly determines the soil's ability to support plant growth. Different soil textures affect the soil's ability to store and conduct water, and to store and provide different plant nutrients. The relative composition of three soil particle sizes: sand (2–50µm), silt (50–2µm), and clay (<2µm) (Soil Survey Staff, 1998). Soil texture can be directly observed physically in the field by taking a clump of soil, wetting it, feeling its texture, and identifying it using the USDA (United States Department of Agriculture) data. Soil texture indirectly influences plant growth and production because it is directly related to groundwater availability and plant root development (Maghfiroh *et al.*, 2022).

The COLE value is frequently used by both soil scientists and engineers to describe the soil's ability to expand and contract. The swelling and shrinking conditions can be used to classify soils and predict their properties for agricultural and engineering purposes. The COLE value can be used for soil genesis and characterization analysis, as well as soil pedology (Lal and Shukla, 2004). Soils high in sand have a coarse texture, are easy to work, and absorb water easily, making them considered light soils. Heavy soil, on the other hand, is soil that contains a lot of clay, has poor water permeability, poor aeration, is sticky, and is difficult to manage. Each fraction has different sizes and properties. The factors that influence the degree of soil wrinkling are its weight. The higher the clay content, the greater the degree of soil wrinkling. However, the presence of organic matter in the soil can have the opposite effect. The higher the organic matter content, the lower the degree of soil wrinkling (Sutanto, 2005).

Lucian (2016) showed that the coefficient of linear extensibility that ranged from 0.09 to 1.15 clearly indicated soils with high to very high shrink–swell potential. Lastly, a direct relationship existed between COLE and colloids contents with high degree of correlation (correlation coefficient = to 0.942 and 0.824 for samples RC5 and RB3 respectively) providing a confirmation to the presence of high to very high expansive potential of the soils. According to Umbugadu *et al* (2021) there are three soil samples, UAA3, UAA 16 and UAA 35 fall under the slight with minimum or no impact to infrastructure that were constructed around the vicinity. Samples UAA2, UAA4, UAA5, UAA6 and UAA 33 have moderate category. According to Yan *et al* (2025), it is stated that for the samples with medium COLE, the model based on clay contents correctly classified 57% of the samples, which was worse than the other models. The best model was the one comprising clay and OC contents. For the samples with high COLE, the model based on clay content alone and clay and OC contents correctly classified all three soil samples. For the samples with very high COLE, the wh based model correctly classified all the 11 soil samples.

MATERIALS AND METHODS

This research was conducted from April to June 2024 in Ultisols and Inceptisols from Siborong-Borong District, North Tapanuli Regency, North Sumatra Province at ± 1500 meters above sea level. Soil analysis was conducted at the Research and Technology Laboratory of the Faculty of Agriculture, University of North Sumatra. The materials used in this study were Ultisol soil samples (Silait-lait and Sitabo-tabo Villages) and Inceptisol soil samples (Lumban tonga- tonga and Parik Sabungan Villages). The tools used in this study were a soil drill to take soil samples, a hoe for first removing weeds from the soil surface, a tape measure to measure soil depth, a camera for documentation purposes, clear plastic bags for sampling, labels for marking samples and stationery. This research was conducted by using descriptive quantitative method. Soil samples were taken by using stratified sampling techniques at depths of 0-20 cm and 21-40 cm. The parameters measured in this research were the soil swelling and shrinking value (COLE method), soil texture (hydrometer method) and soil pH (electrometric method). The COLE value is calculated using the following Eq 1 below (Grossman *et al*, 1968) :

$$COLE_{ws} = (\gamma < 2mm/\gamma 33 < 2mm)^{1/3} - 1 \quad (1)$$

where : $COLE_{ws}$ = coefficient of linear extensibility on a whole-soil base in cm.cm-1; $\gamma_{<2mm}$ = dry density, oven-dry or air-dry, on a <2 mm base (g.cm^{-3}) and $\gamma_{33<2mm}$ = dry density at 33 kPa water retention on a <2 mm base (g.cm^{-3}). COLE is a good indicator of field behaviour of soils which is used for characterization in Table 1 categorized soils based on their COLE values below.

Table 1. Range of COLE

COLE	Rating
0.00 – 0.03	Low
0.03 – 0.06	Moderate
0.06 – 0.09	High
> 0.09	Very high

Source : Vaught, *et al* (2006)

RESULTS AND DISCUSSION

Siborong-borong District is a district in North Tapanuli Regency, North Sumatra Province. Geographically, Siborong-borong District is located between 99°00'50.80' East Longitude and 2°11'12.05' North Latitude. Siborong-borong District has an area of 279.91 km² at an altitude of 1,100-1,500 meters above sea level. The majority of Siborong-borong residents work as farmers. The most dominant agricultural sector in this district is the food crop sector, including rice, secondary crops, and horticulture (BPS, 2023).

Cole value, clay content and soil acidicity

Table 2 shows that the COLE value analysis results are classified as low tand moderate. The value of COLE at the research location ranges from 0.02 to 0.06. The table shows that the COLE value analysis is divided into two categories: low and moderate. Meanwhile, the soil clay percentage parameter obtained results with a clay percentage of <15% with sandy loam and clayey sand textures, while the pH obtained was at 4.75-5.91 with acidic and slightly acidic criteria.

Table 2. COLE Values, Clay Content dan Soil Acidicity (pH)

Village	Sampel	COLE Value		Clay (%)		pH	
		0-20	20-40	0-20	20-40	0-20	20-40
Silait-lait	U_1	0.04 (M)	0.03 (M)	11.60% (SL)	10.00% (SL)	5.01 (A)	5.90 (SA)
	U_2	0.06 (M)	0.05 (M)	13.60% (SL)	1.002% (SL)	4.75 (A)	5.80 (SA)
	U_3	0,02 (L)	0.01 (L)	8.00% (SL)	7.60% (SL)	5.31 (A)	5.74 (SA)
	U_4	0,03 (M)	0.01 (L)	9.60% (SL)	8.00% (SL)	5.10 (A)	5.63 (SA)
Sitabo-tabo	U_5	0.06 (S)	0.04 (S)	13.00% (SL)	11.00% (CS)	5.85 (SA)	5.59 (SA)
	U_6	0,03	0.02	9.76 %	9.00 %	5.68	5.91 (SA)

		(S)	(R)	(SL)	SL()	(SA)	
	U_7	0.03 (M)	0.02 (L)	10,00% (CS)	9.60 % (SL)	5.31 (A)	5.71 (SA)
	U_8	0.04 (M)	0.03 (M)	10.00% (CS)	9.76% (SL)	5.54 (A)	5.37 (A)
Lumban Tonga-tonga	I_1	0.06 (M)	0.05 (M)	14.00% (SL)	13.60% (SL)	5.45 (A)	5.60 (SA)
	I_2	0.06 (M)	0.05 (M)	13.76% (SL)	13.04% (CS)	4.95 (A)	5.56 (A)
	I_3	0.04 (M)	0.03 (M)	9.99% (SL)	9.76% (SL)	4.87 (A)	5.69 (SA)
	I_4	0.03 (M)	0.02 (L)	9.16% (SL)	9.04% (CS)	5.04 (A)	5.62 (SA)
Parik Sabungan	I_5	0.04 (M)	0.03 (M)	10.00% (SL)	9.80% (SL)	5.55 (M)	5.63 (AM)
	I_6	0.04 (M)	0.03 (M)	9.99% (CS)	9.76% (SL)	5.67 (SA)	5.80 (SA)
	I_7	0.03 (M)	0.02 (L)	9.76% (SL)	9.36% (SL)	5.62 (SA)	5.40 (A)
	I_8	0.04 (M)	0.03 (M)	10.04% (SL)	9.76% (CS)	5.65 (SA)	5.32 (A)

Note : (U : Ultisols; I : Inceptisols; L : Low; M : Moderate; SL : Sandy Loam; CS: Clayey Sandy; A : Acidic; SA : Slightly Acidic)

The COLE value analysis results for this soil are classified as low to moderate. COLE values range from 0.02 to 0.06. COLE values are divided into three categories: low (<0.03) found in samples U_3, U_4, U_6, U_7, I_4, and I_7 at a depth of 40 cm; medium (0.03-0.06) found in samples U_1, U_2, U_5, U_8, I_1, I_2, I_3, I_5, I_6, and I_8; high (0.07-0.09) and very high (>0.09). The datas soil of Ultisols and Inceptisols from Siborong-borong district showed similar datas. Both soil types, at depths of 20 and 40 cm, had COLE values in the low to moderate category. A moderate COLE (Coefficient of Linear Extensibility) value tends to be considered better for agriculture than a high COLE value. A higher COLE is often associated with soils that have a large shrinkage and swelling capacity, which can develop cracks during dry conditions and cause problems in soil stability and interfere with plant root growth. Soils with a low or moderate COLE are generally more stable, minimize drastic changes in soil volume, and are better for agriculture because they can support more consistent root growth and reduce the risk of soil erosion. Fanning and Fanning (1989) stated that soils with a moderate COLE value can maintain better soil structure and prevent damage due to drying or excessive wetting.

One factor influencing a soil's COLE value is the type of clay mineral. Soil with a high content of montmorillonite clay minerals can result in a high COLE value. When soil has a high COLE value, it can negatively impact agriculture, as it is highly susceptible to swelling and shrinkage. During dry conditions, cracks in the soil can inhibit plant roots and cause the soil to become very hard. During the rainy season, the soil becomes very heavy, difficult to cultivate, and muddy due to obstructed drainage (Sunarminto and Santosa, 2008). According to Lal (2008), this can interfere with soil cultivation and water movement, leading to drainage problems. During this process, the soil may lose nutrients bound in the expanding montmorillonite layers.

The results of the soil texture analysis in this study revealed two types of soil texture : sandy loam and clayey sand, with all samples containing <15% clay. The highest clay percentage was found in sample I_1 at a depth of 20 cm (14%), while the lowest clay percentage was found in sample U_3 at a depth of 40 cm (7.6%). Soil with a high sand content will have a coarse texture, be easy to cultivate, and allow water to permeate easily, and is referred to as light soil. Heavy soil, on the other hand, is soil with a high clay content, has poor water permeability, poor aeration, and is sticky and difficult to manage. Each fraction has different sizes and properties. The factors influencing the degree of soil wrinkling are its weight. The higher the clay content, the greater the degree of soil wrinkling. Soil is considered clayey if its clay content is greater than 35%, and its capacity to retain water and plant nutrients is high. Water is absorbed with high energy, making it difficult to release, especially when dry, making it less available to plants. Loamy soil is characterized by a proportion of sand, silt, and clay that falls between sandy and clayey soils. Therefore, aeration and air flow are quite good, and the ability to retain and provide water for plants is high (Islami and Utomo, 1995). According to Sari and Basuki (2025), two soil texture classes were observed in the two observed Inceptisol soil horizons. Horizon A exhibits a texture class of sandy clay loam. This soil texture produces soil that is quite good at retaining water and nutrients, and also has good drainage due to its sand content. Meanwhile, horizon B exhibits a texture class of sandy loa. This soil texture has excellent drainage but is less able to retain water and nutrients compared to soils containing more clay (Zega, 2024). Overall, it can be seen that the texture of Inceptisol soil is quite good for supporting plant growth.

The results of the soil acidity analysis (pH) in this study were categorized as acidic to slightly acidic. Table 1 shows the analysis results of the soil samples, which are categorized as acidic with values of 4.75-5.55 and slightly acidic with values of 5.59-5.91. Soil pH is generally divided into 6 categories, namely very acidic (<4.5), acidic (4.5-5.5), slightly acidic (5.6-6.5), neutral (6.6-7.5), slightly wet (7.6-8.5), and wet (8.5). Based on the analysis results, this soil acidity level is the ideal pH. Soil pH is one of the most important chemical properties of soil because it affects plant growth. The pH value indicates the presence of ions. In acidic soil, the soil solution contains more hydrogen ions (H^+) than hydroxyl ions (OH^-), conversely, in alkaline soil, the soil contains more hydroxyl ions (OH^-) than hydrogen ions (H^+) (Kusuma *et al*., 2014). A soil pH value ranging from 5.5 to 6.5 is the optimum pH for plant growth. One cause of acidic soil is weather, because during the rainy season, rainwater carries nitric acid, which, if absorbed by the soil, can affect the content in the soil (Palupi, 2015).

CONCLUSION

Ultisols and Inceptisols from Siborong Borong District have low and medium COLE values, sandy loam and clayey sand soil textures with clay percentages <15%, soil pH in the acidic and slightly acidic categories. It is necessary to add lime-based amendments to increase the pH and aggregation of Ultisol and Inceptisol soils in several villages in Siborong-borong District.

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