MORPHOLOGICAL, CHEMICAL, MINERALOGICAL PROPERTIES AND SOIL CLASSIFICATIONS IN SOME TOPOSEQUENS OF MAMUJU DISTRICT WEST SULAWESI

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ABSTRACT

This study determines the morphological, chemical, mineralogical properties, and soil classification in several toposequences in Mamuju District, West Sulawesi. The research method used is a descriptive exploratory method supported by laboratory analysis data. The results showed yellow and brown soil color, clay texture, subangular structure, slightly sticky consistency, and gradually diffuse horizon boundaries. The Cation Exchange Capacity ranges from Medium to high, very low to low base saturation, and low carbon percentage. The topsoil and subsoil mineral content are dominated by clay minerals and other minerals such as biotite, opaque, muscovite, and feldspar. Soil classification is classified into the Udepts Suborder, Great Group Dystrudepts, and Typic Dystrudepts Subgroup (Profiles 1 and 3). In contrast, Profile 2 is classified into Suborder Humult and Great group Haplohumult and Subgroup Typic Haplohumult.

Keywords: Soil, toposequence, Mamuju, mineral

INTRODUCTION

The development of soil profile formation is influenced by topography mainly in three ways: the direction of movement of materials in solution from one place to another, the level of topsoil displacement by erosion, and the amount of rainfall absorbed and stored in the soil (Weil & Brady, 2016). The difference in topography means that the soil profile that develops with the same parent material and the age at the same zonal will form different soils (James G Bockheim, 2014). Topography variations that develop from these conditions also result in variations in the soil profile called toposequens (Breemen & Buurman, 2003).

Soil morphology is soil properties that can be observed and studied in the field (Hardjowigeno, 1993). Knowledge of soil morphology can provide an overview of changes or evolution in the soil. Observing the description and interpretation of the soil profile properties are usually carried out on a two-dimensional vertically cut soil profile with a soil surface area of not more than one square meter, but the depth can vary. Specific soil formation processes are known by relating the soil properties to each horizon. Determination of the diagnostic horizon that requires identification of the presence of a clay film (argillic/argic horizon) cannot be performed. Because of that, this method often creates problems in determining the classification of the soil (J. G. Bockheim, Gennadiyev, Hartemink, & Brevik, 2014)

In Indonesia, Dai dan Pape (1976) first carried out morphological studies on soils in the Banten area, then continued by several other researchers on soils in the Bogor-Jakarta area (Astiana, 1982; Mulyanto *et al.*, 1999). Soil morphology and mineralogy have become an important science in studying weathering processes of source rocks and the formation and classification of soils (Ahmad, Lopulisa, Imran, & Baja, 2019; Stoops, 2018).

Thus, research on genesis and soil classification in Indonesia is mostly carried out using chemical, physical, and mineral analyses of soil samples in each horizon (USDA (United Stated Department of Agricuture), 2014).

METHODOLOGY

This research was conducted in Papalang District, Mamuju Regency, West Sulawesi Province. This research is an exploratory, descriptive study whose implementation was carried out by surveying the field and supported by data from laboratory analysis conducted in the Hasanuddin University laboratory.

The equipment used is GPS (Global Positioning System), meter, sample ring, Munsell Soil Color Chartbook, guide knives, markers, and laboratory equipment for soil chemical analysis. The materials used are satellite imagery of Mamuju Regency 1: 175,000 scale source: spot 4 imagery, 2008 recording, 2008 Aster image, Indonesia's 1999 Earth Map at 1:50,000, and the Mamuju Regency Administration Map. In addition, a 1:500,000 Land System map was used, a 1:500,000 land Cover Map, a 1:500,000 Slope Map, a 1:500,000 Mamuju Land Map, and a 1:500,000 Mamuju Forest area map, soil samples. Intact and disturbed are taken from each horizon. The research location chosen was at a slope of 3%, 12%, and 35%.

Research Stages

The survey method determines morphology, physical, chemistry, and micromorphology in the soil classification process from each profile to the Subgroup category (USDA (United Stated Department of Agricuture), 2014). The preliminary survey (Pre-survey) carried out in this study was to determine the research location by conducting field visits based on the Land Unit Map (SPL) of Papalang District. Furthermore, in each profile, observations were made for morphological data, namely landscapes, macro and microtopography, and the surrounding environment, including vegetation, land use, drainage, altitude, and geographical location entered into the profile form. Analysis of chemical and mineral properties of soil in the laboratory is carried out by taking soil samples on each horizon or soil layer in a composite manner and taking undisturbed soil using a ring sample for mineral analysis. Soil classification to the Subgroup level is carried out by examining the soil's physical and chemical morphological characteristics plus soil mineral data. Observation Parameters and Analysis Method can be seen in Table 1.

Table 1. Observation Parameters and Analysis Methods.

Observation Parameters	Tool and Methods
Soil Morphology	
Structure	Field observation
Consistency	Field observation
Color	Munsell Soil Color
Horizon boundary	Field observation
Chemical Characteristic	
Soil pH (H_2O) and (KCl)	Extraction (1 : 2.5)
Cation Exchange Capacity (CEC)	Extraction with Ammonium Acetat at pH 7
Base saturation	Extraction with Ammonium Acetat at pH 7
C-Organic	Walkley and Black
Physical Characteristics	
Texture	hydrometer
Mineral	
Type of mineral	Ring sample and thin Section

RESULT AND DISCUSSION

Morphology and chemical characteristics

Boda Boda Profile

Boda-Boda profile is located about 3 meters above sea level with a slope of 3% on the North-South exposition at the foot of the slope, with coordinates (S: 020 24' 0.1"; E:1190 11', 32.5' '). The dominant vegetation is grass, cocoa, banana, rambutan, corn, and langsat. Surface and inside drainage are generally good, characterized by the absence of standing water on the soil surface and its surroundings. The Effective depth was 125 cm (Figure 1).

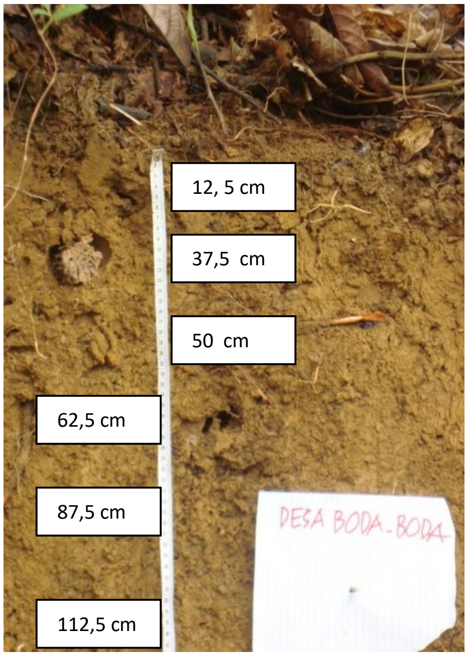

Figure 1. Soil profile of Boda –Boda

The texture is clay, the consistency is rather sticky, and the horizon boundary gradually diffuses in all layers (Table 2). The color of the soil is generally brown, and the bottom layer is yellow. This indicates that there is still much decaying organic matter in the upper layer (Ahmad, Farida, & Lopulisa, 2021). The color still tends to be dark (brown) and the yellow bottom layer, indicating the reduced decomposition of organic matter, and drainage is disturbed. High soil organic matter can be a parameter of litter decomposition triggered by the activity of soil organisms (Singgih et al., 2014). The groundwater level decreases, which results in improved soil aeration, soil moisture, and temperature, which causes chemical activity, yellow watery iron minerals will occur in the soil.

Tabel 2. Morphological characteristic of Boda-Boda Profile

Depth (cm)	Color	Texture	Structure	Consistency	Horizon boundary
		Profile 1 (Boda –Boda Area)			
0 - 12.5	10 YR 4/4 (brown)	Clay	Angular blocky	slightly sticky	gradually
12.5 – 37.5	10 YR 3/4 (brown)	Clay	Angular blocky	slightly sticky	diffuse
37.5 - 50	2.5 YR 4/4 (yellow)	Clay	Angular blocky	slightly sticky	diffuse
50 – 62.5	10 YR 4/4 (brown)	Clay	Angular blocky	slightly sticky	diffuse
62.5 – 87.5	10 YR 5/6 (brown)	Clay	Angular blocky	slightly sticky	diffuse
87,5 – 112.5	2.5 Y 4/3 (brown)	Clay	Angular blocky	slightly sticky	diffuse
>112,5	2 Y 5/4 (yellow)	Clay	Angular blocky	slightly sticky	diffuse

Chemical Characteristic

Soil acidity (pH) decreases from top to bottom at various depths. The moderate carbon content in all layers, CEC is high in the top layer and moderate in the soil layer below. Base Saturation (K.B.) is very low from top to bottom (Table 3). It indicates that at low pH, only the clay permanent charge and some organic colloidal charge hold the ions that can be replaced through cation exchange capacity (CEC). On the other hand, hydrogen bound to organic colloids and clays ionizes with increasing pH and can be replaced. It is also seen that at the same pH, the CEC is different, possibly due to the different levels of organic matter. It is also because the topographic position in this area is relatively flat at 3% toposequence, so it still has a relatively thick solum. The value of organic matter and CEC are relatively the same in all layers except for the top layer. This indicates that organic matter contributes to the exchange of organic matter. Organic matter is a source of plant nutrients and energy from soil microorganisms(Susilawati, Mustoyo, Budhisurya, Anggono, & Simanjuntak, 2013). In carrying out these functions, organic matter is greatly influenced by its source, composition, smoothness of its decomposition, and decomposition results.

Tabel 3. Chemical Characteristic of Boda-Boda Profile

Depth (cm)	pH	C-Organic (%)	CEC (c mol/kg)	Base saturation (%)
Profile 1 (Boda –Boda Area)				
0 - 12.5	5.20 (M)	2.55 (S)	26.33 (S)	18.50 (SR)
12.5 – 37.5	5.20 (M)	2.43 (S)	23.59 (S)	16.70 (SR)
37.5 - 50	5.15(M)	1.82 (S)	21.59 (S)	15.10 (SR)
50 – 62.5	5.10(M)	1.38 (S)	21.15 (S)	15.50 (SR)
62.5 – 87.5	4.70(M)	1.43 (S)	19.28 (S)	18.35 (SR)
87,5 – 112.5	4.56(M)	1.42 (S)	18.88 (S)	18.50 (SR)
>112,5	4.55(M)	1.41 (S)	18.87 (S)	18.45 (SR)

Noted: M: acid S: moderate S.R.: very low

Profile Salumasa

Salumasa's profile is about 50 meters above sea level, 12% slope with North-South exposition in the middle of the hill (Figure 2). The dominant vegetation is grass, cocoa, banana, rambutan, mango, and langsat. Surface and internal drainage are generally good. The effective depth was 125 cm.

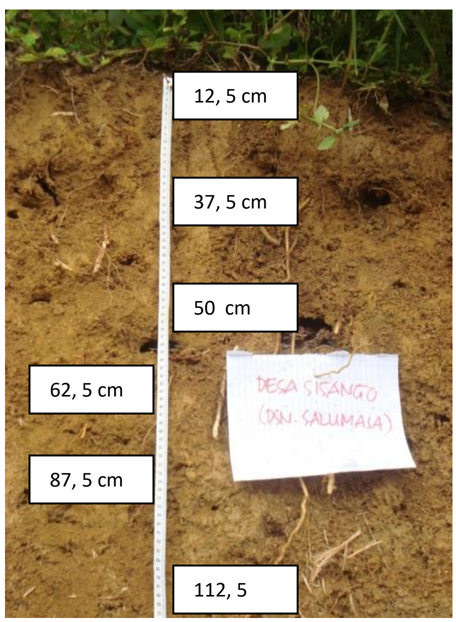

Figure 2. Salumasa profile

The texture is clayey, the consistency is a bit sticky in all soil layers, and the horizon boundary gradually increases in the top layer, then blends in all layers (Table 4). The color of the soil is brown and in all layers, indicating that in the upper and lower layers, the remnants of decaying organic matter are added to the clay texture, which causes slow water movement so that the color of the soil is still tends to be dark (brown). The angular blocky soil structure also indicates this in all soil layers, which is generally located in the B horizon. Due to high rainfall in the study area, the granular structure in the upper (horizon) layer, so that the soil in the top layer is eroded from the top layer to below it (B horizon) so that the horizon boundary fades at the top layer and diffuses to the layer below it.

Table 4. Morfology of Salumasa Profile

Depth (cm)	Color	Texture	Structure	Consistency	Horizon Boundary
		Profile 2 (Salumasa)			
0 - 12.5	10 YR 4/4 (Brown)	Clay	Angular blocky	slightly sticky	gradually
12.5 – 37.5	10 YR 3/6 (Brown)	Clay	Angular blocky	slightly sticky	diffuse
37.5 - 50	10 YR 4/6 (Brown)	Clay	Angular blocky	slightly sticky	diffuse
50 – 62.5	10 YR 4/6 (Brown)	Clay	Angular blocky	slightly sticky	diffuse
62.5 – 87.5	10 YR 5/6 (Brown)	Clay	Angular blocky	slightly sticky	diffuse
87,5 – 112.5	10 YR 6/6 (Brown)	Clay	Angular blocky	slightly sticky	diffuse
>112,5	10 YR 6/8 (Brown)	Clay	Angular blocky	slightly sticky	diffuse

Chemical Characteristic

Soil acidity (pH) is acidic in all soil layers (Table 5). The carbon content varies; the top layer is low to medium and then very low in the layer below. CEC is classified as moderate in the upper layer to the lower layer. Base Saturation (B.S.) is very low from top to bottom. A positive correlation between pH and base saturation is seen in this profile, where the pH is low (acidic), the base saturation is also low. The BS is about 20% to 25%, this indicates that it is about 1/5 to 1/3 part of the total CEC is occupied by basic cations (Ca, Mg, K, Na), and about 70% - 80% or 2/3 to 3/5 parts of cations Al^{3+} and H^{+} are other cations that are easily absorbed. Whether or not H^{+} ions from the roots easily replace the cations depends on the saturation of the cations in the adsorption complex; if the saturation is high, they are easily replaced, and vice versa if the saturation is very low.

Tabel.5. Chemical Characteristic of Salumasa

Depth (cm)	pH	C-Organic (%)	CEC (c mol/kg)	Base saturation (%)
Profile 2 (Salumasa)				
0 - 12.5	4.77 (M)	1.86 (R)	23.40 (S)	20.50 (R)
12.5 – 37.5	4.55 (M)	2.20 (S)	20.42 (S)	21.20 (R)
37.5 - 50	4.54 (M)	1.43 (R)	21.45(S)	21.15 (R)
50 – 62.5	4.50 (M)	0.77 (SR)	21.50 (S)	22.30 (R)
yy62.5 – 87.5	4.51 (M)	0.77 (SR)	19.65 (S)	22.30 (R)
87,5 – 112.5	4.50 (M)	0.77 (SR)	19.63(S)	21.25 (R)
>112,5	4.50 (M)	0.76 (SR)	19.61 (S)	21.23 (R)

Noted: M: acid S: moderate S.R.: very low

Profile of Sisango

The Sisingo profile is about 129 meters above sea level with a 35% slope, North-South exposition on the upper slope (Figure 3). The dominant vegetation is grass, cocoa, banana, rambutan, mango, and langsat. Surface and internal drainage are generally good. The Effective depth was 110 cm.

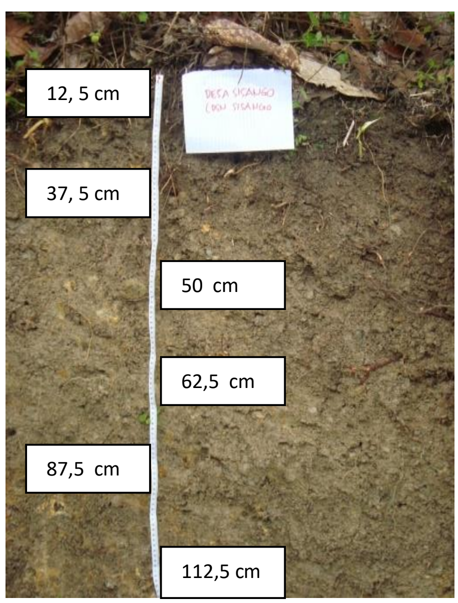

Figure 3. Profil Sisango

Clay texture, angular blocky structure, slightly sticky consistency in all soil layers, gradual horizon boundaries in the top layer, and diffused in all layers (Table 6). The position on a slope of 35% with relatively similar morphological conditions on a profile with a slope of 12%. This is probably because this area still has a lot of vegetation, especially grass and plantation crops that can hold water that falls to the soil. So that erosion does not occur, although it is undeniable that this condition will affect drainage and groundwater levels in the long term. When soil drainage is poor, organic matter will accumulate because the soil lacks oxygen, especially when water is stagnant. Consequently, soils on large slopes will have a thin solum, low organic matter content.

Table 6. Morfology of Sisango Profile

Depth (cm)	Color	Texture	Structure	Consistency	Horizon Boundary
		Profile 3 (Sisango)			
0 - 12.5	10 YR 3/2 (Brown)	Clay	Angular blocky	a bit sticky	gradually
12.5 – 37.5	10 YR 6/4 (Brown)	Clay	Angular blocky	a bit sticky	diffuse
37.5 - 50	10 YR 3/3 (Brown)	Clay	Angular blocky	a bit sticky	diffuse
50 – 62.5	10 YR 4/4 (Brown)	Clay	Angular blocky	a bit sticky	diffuse
62.5 – 87.5	10 YR 5/4 (Brown)	Clay	Angular blocky	a bit sticky	diffuse
87,5 – 112.5	10 YR 3/6 (Brown)	Clay	Angular blocky	a bit sticky	diffuse
>112,5	10 YR 5/6 (Brown)	Clay	Angular blocky	a bit sticky	diffuse

Chemical Characteristic

This profile's soil acidity (pH) is acidic in the topsoil up to a layer of 87.5 cm and very acidic in the lower layers. The carbon content varies, namely low in the top layer to 62.5 cm and moderate in the soil layer below (Table 7). CEC is classified as high in the upper layer to a layer of 50 cm and then low to the lowest layer. BS is low from the top layer to the 50 cm layer and gradually gets very low to the bottom layer.

The low pH value is influenced by soil colloids (clay and organic), base saturation, the type of cations adsorbed, and other environmental factors. Washing of bases, hydrolysis of H and Al ions, decomposition of organic matter, and oxidation of pyrite compounds are also one of the causes of soil acidity. Acidic soils are potential for expansion and increased agricultural production but need liming to raise pH, eliminate Al toxicity, and provide Ca as a nutrient.

Table 7. Chemical Characteristic of Sisango Profile

Depth (cm)	pH	C-Organic (%)	CEC (c mol/kg)	Base saturation (%)
Profile 3 (Sisango)				
0 - 12.5	5.06 (M)	1.28 (R)	27.00 (T)	26.00 (R)
12.5 – 37.5	5.25 (M)	1.26 (R)	26.65 (T)	26.13 (R)
37.5 - 50	5.00 (M)	1.24 (R)	23.57 (T)	26.06 (R)
50 – 62.5	4.75 (M)	1.60 (R)	15.46 (R)	17.78 (SR)
62.5 – 87.5	4.50 (M)	2.05 (S)	15.51 (R)	18.56 (SR)
87,5 – 112.5	4.48(SM)	2.05(S)	15.50 (R)	18.88 (SR)
>112,5	4.45 (SM)	2.04 (S)	15.49 (R)	18.78 (SR)

Noted: M: acid S: moderate S.R.: very low

The CEC value of the soil affects the availability of nutrients for plants. Soils with a high CEC can absorb more nutrients but are rather difficult to release into solution, making them difficult to be available to plants, and therefore more fertilizer is needed. On the other hand, soils with a low CEC store fewer nutrients but easily release them into a solution so that they are easily available to plants.

Minerals

Table 8 identified six minerals found in profiles 1, 2, and 3: Quartz, Biotite, Opaque, Muscovite, Feldspar, and clay minerals. Quartz (SiO2) is a primary silicate mineral: The framework structure is stable and resistant to weathering (Sireesha & Naidu, 2015). Weathering speed is very slow. It consists of 12% igneous rock and 66.8% sandstone. Found in all profiles, both on the top and bottom layers. The quartz found ranged from 10% - 15%, measuring 0.08 mm - 1.2 mm.

Table 8. Soil Micromorphology

Minerals	Contains in each layer (%)					
	Profile 1 (Boda Boda)		Profile 2 (Salumasa)		Profile 3 (Sisango)	
	upper	bottom	upper	bottom	upper	bottom
Quartz	10	10	10	15	10	10
Biotite	10	10	10	10	10	15
Opaque	5	5	5	15	5	10
Muscovite	5	-	5	5	10	15
Feldspar	10	10	5	-	5	-
Clay	50	60	55	50	60	35

Biotite (K(Mg, Fe)3(Al, Fe)Si3O10(OH, F)2) is a primary silicate mineral: Weathering rate is very high. Nutrient content: K2O (6-9%); MgO(2 - 20%). Biotite was found in all profiles in both the upper and lower layers. The number of Biotite minerals found ranged from 10% - 15%, measuring 0.05 mm - 0.6 mm. Biotite is the main resource for plant nutrients (Ahmad, Lantera, & Jayadi, 2020; Regmi, Yoshida, Dhital, & Pradhan, 2014; Suryani, Lopulisa, & Ahmad, 2021)

Muscovite (KAl2(AlSi3O8)O10(OH)2) is a primary silicate mineral: Weathering rate is low. Nutrient content: K2O (8 - 11%) ; MgO (0 – 3%). The Muscovite was found in all bottom layer profiles. Muscovite mineral amounts range from 5% - 15%, measuring 0.04 mm - 0.3mm. K-Feldspar (KAlSi3O8) is a primary silicate mineral. Weathering speed is low/slow. K2O nutrient content (9 – 15%) ; CaO (0% – 3 %). The amount of K-Feldspar minerals found ranged from 5% – 15%, measuring 0.04 mm – 0.3 mm in the top 1, 2, and 3 layer profiles, while the 2 3 layer bottom profile was not found. Opaque, an oxide mineral is found in all profiles, both top, and bottom layers. Opaque minerals are found around 5% - 15%, with a size of 0.01 mm - 0.8 mm. Clay minerals, which are secondary minerals resulting from alteration of primary minerals, dominate in profiles 1, 2, and 3 with 35% - 60%.

The high percentage of minerals in the lower layers comes from the soil's parent material, while the high percentage of minerals in the upper layers comes from transporting the soil from higher places.

Soil Classification

The classification system used for soil grouping at the research site is the USDA Soil Taxonomy System (1999). The preparation of the taxon starts from a high taxon level to a low taxonomic level in the following category: Order, Suborder, Great Group, Subgroup. Soil classification is presented in Table 9.

Table 9. Soil classification on each profile

No	Profile	Location	Category			
			Ordo	Sub Ordo	Great Group	Sub Group
1	P_1 T_4	Boda-Boda (S: 02^0 24’ 0,1’’ E:$119^0$11’32,5’’)	Inceptisol	Udepts	Dystrudepts	Typic Dystrudepts
2	P_2 T_4	Salumasa (S: 02^0 24’ 20’’ E: 119^0 12’ 38’’)	Ultisol	Humult	Haplohumult	Typic Haplohumult
3	P_3 T_4	Sisango (S: 02^0 23' 56" E: 119^0 13’ 42’’)	Inceptisol	Udepts	Dystrudepts	Typic Dystrudepts

Morphological, physical, chemical, and mineralogical data from the study profile show that the soil in the study area has undergone intensive weathering and leaching. Collaboration high rainfall and parent material affected the low accumulation of clay and base saturation, increasing weathering minerals and rock fragments (Yusnita, Ahmad, & Solle, 2020).

Profiles 1 and 3 are categorized as Inceptisols because the parent material has changed due to soil formation processes which are quite strong, which distinguishes them from Entisols but not intensive enough for the type of horizon required for the Ultisol order. Inceptisols are eluvial soils i.e. soils lose their elements by leaching and do not have a large accumulation horizon of elements (Lopulisa, 2004), but this is not a necessary condition for their identification, has a cambic horizon, which can form (1) groundwater fluctuations followed by removal or loss of iron, (2) weathering of iron minerals causing the B horizon to be redder than the C horizon, in free drainage and low carbonate soils, (3) highly calcareous materials in wet areas that have undergone leaching, (4) in soils with arid and semi-arid climates where prismatic structures have developed and carbonates have been dispersed or leached (Soil Survey Staff, 1999). Profiles 1 and 3 include the cambic horizon because they have a very fine texture, the thickness of the horizon is more than 15 cm, the horizon does not experience aquic conditions and has a clay % greater than the horizon above and below it, but does not meet the argillic criteria.

Inceptisols have the Suborder Udepts, namely Inceptisols, which have a udic soil moisture regime (once moist soil). The Great group level is classified as Dystrudepts because other Udepts that do not have the properties for Sulfudepts (sulfuric horizons whose upper limit is within 50 cm of the mineral soil surface), and Durudepts (Udepts that have durians whose upper limit is within 100 cm of the soil surface). Fragiudepts (having fragipan within 100 cm of the mineral soil surface), and Eutradepts (udepts having one or both of the following properties (a) free carbonate in the soil, or (b) base saturation of 60% or more between a depth of 25 to 75 cm from the mineral soil surface. Furthermore, at the Sub Group level, Typic Dystrudepts are classified, namely the core properties of the group.

Profile 2 is categorized as Ultisol at the Order level. A relatively high organic matter accumulation generally characterizes classification at the sub-order humult level up to the argillic horizon with good drainage. The same level of organic matter accumulation is not found in other sub-orders with the same drainage. The Classification of the Great Group Haplohumult, namely other humults that do not have the requirements for the great group Sombrihumult, Kandihumult, Kanhaplohumult, and Palehumult. Meanwhile, the classification of the sub-group level is Typic Haplohumult, Haplohumult with a certain type, in this case the type of soil with advanced weathering and intensive leaching (accumulation of clay, low weathering minerals, rock fragments and low base saturation).

Conclusions

1. In general, the morphological characteristics, the profile has lost all or part of the A horizon which is indicated by a relatively high chroma color with a generally brown color which is the color of the B horizon. The clay content is relatively high with a clay texture, angular lump structure, slightly sticky consistency, and diffuse and gradual horizon boundaries.

2. Soil chemistry shows that pH in all profiles is acidic, carbon content is very low to moderate, Cation Exchange Capacity (CEC) is moderate to high, and Base Saturation (K.B.) is generally low.
3. Soil micromorphology shows that the top and bottom layers in all profiles contain quartz, biotite, opaque, muscovite, feldspar minerals ranging from 5% to 10%, and clay minerals ranging from 35% - 60%.
4. Soil classification profiles 1 (Boda-boda) and 3 (Sisango) were classified as Typic Dystrudepts, while Profile 2 (Salumasa) was classified as Typic Haplohumult.

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