

Ilmu Pertanian (Agricultural Science)

http://journal.ugm.ac.id/jip
Vol. 9 No. 1 April, 2024: 35–42 | DOI: doi.org/10.22146/ipas.83931

Characteristics and classification of the peat at Toba Highland, North Sumatera, Indonesia

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Article Info

Received: 17th April 2023 Revised: 31st January 2024 Accepted: 18th March 2024

Keywords:

Highland peat land, lowland, soil taxonomy, toba highland

Abstract

Peatland serves as a crucial natural resource with hydrological and other environmental functions essential for all living organisms. In some regions, peat soil isn't limited to lowland areas, it is also found in highland areas. This study is a survey research aiming to examine the characteristics of the highland peatlands of Toba North Sumatera, namely in the Village of Matiti II, Humbang Hasundutan Regency, North Sumatera and lowland peatlands as control of peatlands in general in Sidomulyo Village, Bilah Hilir Subdistrict, Labuhan Batu. The study employed a survey research approach with a descriptive method to determine the differences in the characteristics of highland Toba peat soils. In each area, a representative profile was made, and the soil morphology, characteristics and classification were observed according to the 2014 soil taxonomic classification. Soil samples were taken from each layer in the soil profile for soil analysis in the laboratory. Soil analysis included bulk density, pH H₂O, pH NaF, CEC, base saturation, organic C, total N, C/N, electrical conductivity (EC) and ash content. The results showed that the difference in altitude directly affected the microclimate and the hydrologic conditions, which in turn affected the characteristics of the peat soil. In the context of the Toba highland, the main source of peat soils comes from rainfall. In contrast with the peatland of the lowlands, where the impact of tides is a significant factor, the peat of the Toba highland is affected by the surrounding hills.

INTRODUCTION

Peat is a type of soil that is waterlogged and rich in organic material, undergoing an extremely slow decomposition process. Typically, peat soil has a minimum thickness of 50 cm with organic content (organic C) exceeding 18% (Agus and Subiksa, 2008). It forms in areas with poor drainage, hindering the decomposition of plant and animal remains, resulting in unique characteristics compared to mineral soil (Noor, Masganti and Agus, 2016).

Peatland serves as a crucial natural resource with hydrological and other environmental functions essential for all living organisms. It serves multiple

vital functions, including water storage, biodiversity habitat, protective functions, and productive functions. These critical functions necessitate the protection and preservation of peatlands (Agus et al., 2014).

Peat has a natural capacity to absorb and store water, thus acting as an essential water source in maintaining local water availability. Preserving peatlands can aid in protecting regions from natural disasters such as droughts and floods (Harsono, 2011). Indonesia's peatland ecosystems store a substantial amount of carbon. When peat degrades or burns, the stored carbon is released into the atmosphere in the form of greenhouse gases, primarily carbon dioxide. Therefore, conserving peat in Indonesia is vital for global climate

How to cite: Sarifuddin, Sitohang, E.J., and Mukhlis. (2024). Characteristics and classification of the peat at Toba Highland, North Sumatera, Indonesia. *Ilmu Pertanian (Agricultural Science)*, 9(1), pp. 35–42.

change mitigation efforts (Nurhayati, Aryanti and Saharjo, 2010).

Indonesia boasts the largest expanse of peatlands globally, estimated to cover approximately 20 million hectares. These peatlands are primarily found in Sumatera, Kalimantan, Papua, and to a lesser extent, Java (Sitohang, 2021).

In some regions, peat soil isn't limited to lowland areas; it is also found in highland areas. Soil identification and characteristics indicate that peatlands are fairly widespread in highland areas with altitudes exceeding 1,000 meters above sea level in Indonesia. Highland peatlands are located in Kerinci Regency, Jambi Province, Dogiyai and Deiyai Regency, Papua Province, and Humbang Hasundutan Regency, North Sumatera Province (BBSDLP, 2011). Highland peatlands in Indonesia are located in Kerinci Regency, Jambi Province, Dogiyai Regency, Deiyai, Paniai Papua Province and Humbang Hasundutan Regency, North Sumatera Province (BBSDLP, 2011).

North Sumatera Province has upland peatlands in the Toba caldera area, precisely in Humbang Hasundutan Regency with an area of 6,289 ha. These upland peatlands are found in three subdistricts, namely Lintong Nihuta, Doloksanggul, and Pollung Subdistrict, all of which are in Humbang Hasundutan Regency (Purba, Mukhlis and Supriadi, 2017). Highland peatlands have their unique characteristics because they are not influenced by tidal seawater or coastlines, relying solely on rainfall (Hardjowigeno, 1996).

Therefore, from the description above, this study aimed to examine the physical and chemical characteristics of highland peat and lowland peat soils in North Sumatera.

MATERIALS AND METHODS

This research was conducted in the highland peatlands of Toba in Matiti II Village, Humbang Hasundutan Regency, North Sumatera. Soil sample analysis was carried out at the Laboratory of Oil Palm Research Center and Laboratory of Research and Technology, Faculty of Agriculture University of North Sumatera. The study employed a survey research approach with a descriptive method to determine the differences in the characteristics of Toba highland peat soils.

Three soil samples were collected at different soil layers, specifically at depths of 0–60 cm, 60–90 cm, and 90–130 cm. Each sample from each profile

was analyzed for peat chemical characteristics based on the criteria of Pusat Penelitian Tanah (1983), including bulk density (BD) measured with ring sample, pH $\rm H_2O$ (1: 2.5) and pH NaF measured with electrometric method, soil cation exchange capacity (CEC) at pH 7 determined using ammonium acetate method (Van Reeuwijk, 2002), total soil organic carbon (SOC) analyzed using Walkley and Black method (Van Reeuwijk, 2002), total N analyzed using the Kjeldahl method, C/N ratio and exchange bases (Ca, Mg, K and Na) determined using ammonium acetate method (Van Reeuwijk, 2002), base saturation, electrical conductivity (EC) (1:2.5) measured using electrometric method (EC meter), and ash content measured using Muffle furnace.

RESULTS AND DISCUSSION

General condition of the Toba Highland peat area

The research location was in Humbang Hasundutan (Humbahas) Regency with an altitude of 1,338 –1,414 m above sea level. Humbang Hasundutan Regency is located on the line 2^1-2^28 north latitude and 98^10-98^58 east longitude. Geographically, Humbang Hasundutan is bordered by:

East side : North Tapanuli Regency
South side : Central Tapanuli Regency
West side : Pakpak Bharat Regency

North side : Samosir Regency

Humbang Hasundutan Regency has a climate classified as a wet tropical area with two seasons, namely dry and rainy season. Dry season occurs from April to August, and rainy season usually occurs from September to March. The height of the place from sea level affects the air temperature, that is, every 100 m the temperature will drop by an average of 0.6°; therefore, the higher a place will cause the area to have a lower temperature. The temperature in Humbang Hasundutan Regency ranges from 17°C-29°C, and the average humidity (RH) is 85.94 percent, where most of the western region of Humbang Hasundutan Regency has a hot climate, and the eastern region is a plateau with cold air. The average amount of rainfall in Humbang Hasundutan Regency in 2018 was 228.7 mm/year. The average number of rainy days that occurred in 2018 was 18 rainy days (BPS Humbahas, 2020). Humbahas Regency is one of 8 administrative areas located in the Lake Toba area. The Lake Toba area is dominated by hills or mountains with the slope

of the field consisting of flat with a slope (0–8%), gently sloping (8–15%), rather steep (15–25%), steep (25–45%), and very steep to steep (>45%) (BPS Humbahas, 2020). The 12% area of Humbang Hasundutan Regency is at an altitude below 500 m asl covering parts of Pakkat and Tarabintang Subdistricts; 36% is at 500–1000 m above sea level covering Tarabintang, Baktiraja Subdistrict, parts of Pakkat and Parlilitan Subdistricts; 48% is at 1000–1500 m asl covering Doloksanggul, Pollung, Lintongnihuta, Paranginan, Onanganjang, Sijamapolang Subdistricts, parts of Pakkat and Parlilitan Subdistricts; and 3% is at altitude above 1500 m asl covering Dolok Pinapan area.

Humbang Hasundutan Regency is located in Bukit Barisan area with generally hilly and undulating physiographical conditions, located at an altitude of 330–2,075 m above sea level and is an agribusiness agricultural area with considerable development potential. Humbang Hasundutan Regency is located in the Bukit Barisan mountainous area, so the topography of this area is hilly, undulating, and part of the plateau.

The sampling area for the research is in Matiti II Village in Dolok Sanggul Subdistrict with an altitude of 1,309 m above sea level. The peat area in this area is widely used by the community for agricultural land, such as coffee, rice fields and horticultural crops (chilies, tomatoes and vegetables). Sampling was carried out on the people's 15-year-old arabica coffee plantations. Some agricultural land has been converted into residential housing.

General condition of the lowland peat area

The lowland peat studied in Labuhan Batu Regency is geographically located at 1°41′–2°44′ North Latitude, 99°33′–100°22′ East Longitude with an altitude of 0–2.151 m above sea level. Labuhan Batu Regency is one of the vast regencies located on the east coast in the southeastern part of North Sumatera Province. Geographically, Labuhan Batu Regency is bordered by:

East side : Riau Province

South side : South Labuhan Batu Regency
West side : North Labuhan Batu Regency
North side : North Labuhan Batu Regency

Labuhan Batu Regency consists of 9 sub-districts consisting of 98 villages/wards and is located in the Indo-Australian climate zone characterized by high temperature, humidity, and rainfall throughout the year. In general, the topography presents a flat or almost flat surface relief form and partly forms hills

with varying slopes. The slope ranges from 0-16% with an altitude of 0-370 m above sea level (BPS Labuhan Batu, 2020).

The research location is in Sidumulyo Village, Bilah Hilir Subdistrict, Labuhan Batu Regency with an altitude of 15 m above sea level. The air temperature at the sampling site, namely at PT. Hari Sawit Jaya (Asian Agri), ranges from 29°C–32°C, with an average humidity (RH) of 35.6%. The average amount of rainfall in PT Hari Sawit Jaya (Asian Agri) in 2019 was 8.83 mm, with an average number of rainy days that occurred in 2019 of 11 rainy days.

The peatlands located in PT. Hari Sawit Jaya (Asian Agri) is influenced by the tides of sea water so that there is mineral enrichment due to the tides. The tidal effect of sea water makes peat more fertile so that it can be classified as eutrophic peat.

Toba highland peat soil morphology

Observation on the morphological characteristics of the highland peatlands of Toba includes the depth of the peat soil, color, consistency, topographic boundaries, and layer boundaries. On the highland peatlands of Toba, a representative profile was created in Matiti II Village, Dolok Sanggul Subdistrict (Figure 1). In the profile, soil morphological observations were made according to the Soil Survey Staff (2014) soil observation guidelines, and soil samples were taken from each layer for analysis in the laboratory. The soil profile description of the research location is presented in Table 1 and layers surface 0–60 cm, 60–90 cm, and 90–130 cm are presented in Figure 2.

Based on Table 2, there was a change in soil color from the soil surface to the lower layer. In the representative profile, the morphological condition of the surface tier to the sub-surface layer changed the color of the soil. The color of the soil from the surface layer to the sub-surface layer was getting darker (black), while the sub-surface layer to the subsurface (base tier) did not change color. The Hue value changed from 5 YR to 10 YR, and the value changed from 2.5 to 2, but the chroma value remained 1 in the surface layer to sub surface layer, while in the subsurface layer (base tier) the color the ground was 10 YR 2/1.

The highland peatlands of Toba in the surface and sub-surface to subsurface layers still have a lot of wood fibers to completely decomposed wood ranging from 17–75% of the volume; therefore, they are classified into hemic maturity levels (Soil Survey Staff, 2014)

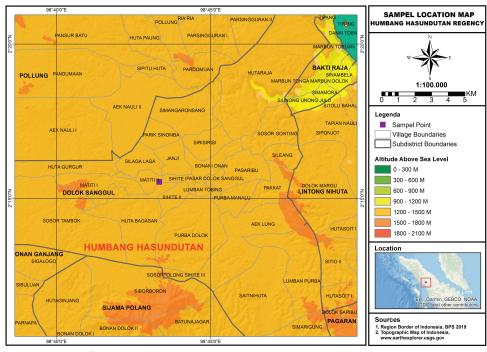


Figure 1. Map of research locations in Toba highland peatland

Table 1. Description of peat morphology in Toba highlands

Location	Matiti II Village, Kecamatan Dolok Sanggul, Kabupaten Humbang Hansundutan
Code	Profile 1
Coordinate	N 02°15.32°
	E 98°43.20°
Classification	Hydric Haplohemist
Physiography	Basin
Slope	0-3% (flat-slightly flat)
Characteristic	
Elevation	1409 m asl
Peat thickness	>3 m
Parent material	Coniferous forest
Layers	0–130 cm Hemist



Figure 2. Layers in depth: (a) 0–60 cm, (b) 60–90 cm (using a drill), and (c) 90–130 cm (using a drill).

Table 2. Physical characteristics of peat soil in Toba highlands

Layer	Depth (cm)	Level of maturity	Soil color	Bulk density (g/cm³)	Consistency	Topography	Layer boudaries
Oe1	0-60	Hemist	Black (5 YR 2,5/1)	0.25	Slightly sticky,	Straight/flat	diffuse
					slightly plastic		
Oe2	60–90	Hemist	Black (10 YR 2/1)	0.16	Slightly sticky,	Straight/flat	diffuse
					slightly plastic		
Oe3	90-130	Hemist	Black (10 YR 2/1)	-	Slightly sticky,	Straight/flat	diffuse
					slightly plastic		

In the Lintong nihuta area, there are organic materials derived from the main material of coniferous forests, which have not been completely decomposed and are still in the form of large logs used by some local communities to large companies, such as Indorayon using the peatland for timber for fuel or charcoal production.

The maturity level of the peatlands of Toba highlands has a hemic maturity level starting from the surface layer to the lower layer (base tier). The level of peat maturity is influenced by the hills surrounding the peat area, which is not far from the peat area. (Purba et al., 2017) stated that the peat area in Dolok Sanggul Subdistrict has added minerals because it is surrounded by hills, which increase the decomposition and maturity level of the peat and accelerate the decomposition process on peat soils.

In lowland peat, the sapric maturity level is on the surface and sub-surface layers, while the lower layer is hemic. The level of maturity in the lowlands is influenced by the intensity of management and the addition of ameliorant material given. Lowland peat has a higher management intensity; this can be seen from the use of peatlands for oil palm cultivation, which has entered 2 times the planting season (second generation crops), and the water level is always maintained throughout the year. Suratman and Sukarman (2016) stated that giving ameliorants to peat soils on plantation land could increase soil fertility, which is indicated by an increase in the value of several soil fertility elements.

The level of peat soil maturity also affects the bulk density of the soil. Generally, the bulk density of peat soil decreases with the increase in the depth of peat soil. The higher the level of peat soil maturity, the higher the bulk density and vice versa. The low value of bulk density indicates the need to select plant types in peat land use for plant cultivation because bulk density is related to the ability of the peat soil

to withstand plant loads, penetration of plant roots, and all physical activities that can affect bulk density. The physical characteristics of peat such as bulk density are related to the load bearing capacity of plants, wherein low bulk density implies low load-bearing capacity of plants (Hartatik, et al. 2011).

In higland peat, the soil color is dark reddish brown (5 YR 2.5/1) to brownish black (10 YR 2/1). Soil color in the Toba highland peat is influenced by the content of organic matter and the level of decomposition in each area, where in the highland peat of Toba organic matter is higher with a slow rate of decomposition. In lowland peat, the color of the peat is dark reddish brown (5 YR 2.5/2) with a higher rate of decomposition of organic matter so that dark humic compounds appear.

The hills that surround the peat area can result in the addition of mineral material in the peatlands of the Toba highlands. The addition of minerals from each of these processes also affects the ash content in the respective peat areas. (Fitra et al., 2019) The main factors that influence ash content are the type of peat soil, the position of existence, type, and thickness.

The result of soil analysis is presented in Table 3. Organic carbon in all layers were classified as very high >5%. In the surface layer, organic carbon levels are higher than in the sub surface layer and increase in the base tier layer. This implies that peat found in highland regions is affected by minerals from nearby mountains, which can reduce the organic content in the peat. Consequently, peat in highland areas tends to have a lower proportion of organic carbon (organic C) compared to peat in other regions. Prasetyo and Suharta (2011) have stated that organic acids that are detrimental to peat can be mitigated by the application of polyvalent cations (Cu²⁺, Fe²⁺, Al³⁺, and Zn²⁺), which enhance the utilization of mineral substances. These cations can help counteract the adverse effects

Layer	Depth (cm)	pH H₂O	pH NaF	Exchangeable bases (m.e/100 g)			ses	CEC EC -(m.e/100g) (mmhos/cm)	C-Org (%)	N-Tot (%)	C/N	Ash content	
	(СП)			K	Ca	Na	Mg	= (III.C/ 100 <u>6</u>)	(111111103/6111)	(70)	(70)		(%)
Oe1	0-60	5.24	8.10	0.69	21.44	0.26	2.19	91	41.63	13.54	0.65	20.83	8.9
Oe2	60-90	4.76	6.95	0.33	19.68	0.45	4.52	53	78.18	9.61	0.87	11.04	3.0
Oe3	90-130	4.76	6.94	0.90	7.95	0.14	3.88	63	49.72	16.60	0.91	18.24	1.7

Table 3. Chemical characteristics of the peatlands of Toba highlands

of organic acids on peat, thereby improving the peat's mineral utilization

Based on Table 3, the cation exchange capacity (CEC) of peat soils is high, with a relatively low base saturation. A high CEC value in peat soil indicates its ability to retain positive ions, such as base cations like calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na). However, despite the high CEC, the base saturation in peat is relatively low. This is attributed to the predominance of hydrogen ions (H+) in peat. Therefore, although peat has a high cation exchange capacity, a significant portion of it consists of hydrogen ions. The high CEC value is also influenced by organic matter, where the high organic matter content in peat causes microelements to form complex compounds with organic acids, making them less readily available. This means that the organic matter in peat can form complex compounds with microelements, such as iron (Fe) and copper (Cu), among others, rendering them less accessible to plants.

This aligns with the statement by Mukhlis et al. (2011) that the CEC of soil is determined by factors like soil texture, organic matter levels, and the types of minerals present in the soil. Therefore, the high CEC in peat is the result of a combination of these factors and has an impact on the availability of essential elements for plants in peat soil.

The electrical conductivity of lowland peat is higher due to an increase in the concentration of salts in peatlands due to tides and runoff from sea water or rivers around the peat. The value of electrical conductivity increases in the subsurface layer of lowland peat due to the deposition of cations in the soil. The increase in electrical conductivity is indicated by higher levels of Ca⁺ and Mg²⁺ cations where some of the EC values in peat water are obtained from the electrical conductivity and soil colloids.

Highland peat soil classification

Representative profile on highland peat is classified based on Soil Taxonomy according to Key to Soil Taxonomy 12th edition (2014).

Ordo; soil in the representative profile contains organic matter and wood chips that are more than 20 mm in diameter and is not so decomposed that it is difficult to knead or break by hand. Some organic soils have a mineral surface layer less than 40 cm thick, organic soils consisting of sapric and hemic materials of three quarters (by volume) or more of the volume of the fibers are derived from the parent wood. Surface layers up to 60 cm deep have a volume weight of less than 0.1 g/cm³. This confirms that the soil from the representative profile fulfills the organic soil characteristics classified as the order of Histosols.

Sub Ordo; soil in the representative profile has a depth of organic matter that is more than the hemic soil material, the half-ripe peat with the original material is still recognizable, when squeezed, the fiber content that is left in the palm is between one-third and two-thirds of the original amount, and there is still a good organic material (fiber) on the surface to the lower tier. This states that the soil is of the order Histosol and has criteria in the hemist sub-order.

Great Group; the results of field observations on representative profiles meet other hemist sub-order categories; therefore, they are included in the great Haplohemist group.

Sub Group; in observing the profile of this great haplohemist group representative, it has a layer of water in the control section, under the surface tier, so it is included in the Hydric Haplohemist sub-group.

Based on the 2014 Key to Soil Taxonomy, the highland peat soil profile located in Matiti II Village, Dolok Sanggul subdistrict, Humbang Hasundutan Regency has the following soil classification: Order:

Histosol, Sub Order: Hemist, Great Group: Haplohemist, and Sub Group: Hydric Haplohemist.

CONCLUSIONS

The difference in altitude has a significant impact on microclimate, including temperature, precipitation, and air humidity, which directly affects the rate of decomposition of organic material in peat soils. Consequently, it also affects the mineral maturity and composition of the soil. Morphology of the peat land on Toba highland indicates a significant variation in color, with the discoloration observed from surface to lower layer (base tier). This change in color can be explained by the higher elevation of the Toba highland, ranging from 1338 to 1414 meters above sea level. The difference in altitude directly affects the microclimate and the hydrologic conditions, which in turn affect the characteristics of the peat soil. In the context of the Toba highland, the main source of peat soils comes from rainfall. In contrast with the peat land of the lowlands, where the impact of tides is a significant factor, the peat of Toba highland is affected by the surrounding hills. Therefore, the hydrological condition and characteristics of its peatland are more closely affected by the rainfall pattern and the topography of surrounding hills.

ACKNOWLEDGEMENTS

The authors would like to thank to Universitas Sumatera Utara for fundingin this research by TALENTA Grant (contract number: 21/UN5.2.3.1/PPM/SPPTALENTA USU/2020, 28 April 2020).

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