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Assessment of physico-chemical parameters of primaeval forest soil in Thanh Chuong District of Nghe An Province, Vietnam

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ABSTRACT

The physicochemical features of soil (PFOS) play an important role in the growth process of flora and vegetative diversity of the primaeval forests. The PFS in the primaeval forest belonging to Thanh Chuong District in Nghe An Province, Vietnam was investigated during 2016-2019 to assess the fertility and productivity status of the soils. To deploy this work, ninety-six soil samples at eight random locations from twenty-four sampling plots represented the upper, middle, and lower of the study area were analyzed for soil texture (ST), bulk density (BD), pH, total nitrogen (TN), total phosphorus (TP), and exchangeable cations (ECs) (K^+, Ca^{2+} and Mg^{2+}). Texturally, the soils were clay loam to sandy clay with average percentages of sands around 41%, silts 19%, and clay 40% while the bulk density of the soils was 0.83-1.41%. The acidic to slightly acidic soil pH (4.01-4.82) and high TN (0.95 -2.66 g/kg) and TP varies from 0.06 and 0.18 g/kg. Correlation analysis of the physicochemical parameters was conducted using the Pearson correlation test in R programming. Analysis showed that the variation in the texture of silt content among the soil depth was minimal.

Key words : Bulk density, physico-chemical, porosity, primeval forest, soil texture

INTRODUCTION

Primaeval forest soil (PFS) plays a vital role in maintaining the sustainable productivity of forest ecosystems (Arévalo-Gardini *et al.*, 2015; Cermák *et al.*, 2018). PFS with good physicochemical features are essential for the maintenance and development of forest ecosystems as well as enhancing processes that maintain environmental quality (FAO, 2015). Accordingly, the vegetation and soils have a cohesive relationship because they are dependent on each other (FAO, 2015; Nelofer *et al.*, 2016). Soils are commonly made up of two properties namely physical, and chemical and will behave according to the proportion of the two key properties (Suleiman *et al.*, 2017; Jaquan *et al.*, 2020). PFOS is significantly dominated by geologic, geomorphologic, gravity chemical interaction, and climate factors such as rainfall, wind, temperature, humidity (Suleiman *et al.*, 2017; Cermák *et al.*, 2018). Soils are included four basic components: minerals, air, water, and organic matter (Joshi and Negi, 2015). In addition, soil properties of primaeval forest ecosystems commonly depend upon a variety of abiotic and biotic factors that vary both spatially and seasonally (Aliyu *et al.*, 2016; Jinquan *et al.*, 2020; John *et al.*, 2020). In most soil samples, on average, minerals represent take up a proportion of approximately 45% of the total volume, water, and air about 50%, and organic matter only remain about 5% (Thomaz *et al.*, 2014). Among abiotic factors such as total ion content, acidity, carbon, nitrogen and total phosphorous vary on the spatial scale in the surface layers of soil (Bensemann *et al.*, 2018; Amonum *et al.*, 2019; Francisco *et al.*, 2021). Specifically, the total ionic contents and acidity independently affect the soil geochemistry and finally the distribution pattern of vegetation in a primaeval forest (FAO, 2015; Nelofer *et al.*, 2016).

The variation of the PFS occurs under

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the changes in climate parameters, soil flora and fauna activities, weathering processes, topography, vegetation cover and other biotic and abiotic variables (Dinh and Shima, 2022; Dinh and Dang, 2022). According to Dang *et al.* (2021), climate factors such as temperature, air humidity and rainfall have no direct influence on the soil composition; however, they can have an indirect effect on plants through soil moisture. For example, if the climate of the area becomes arid, then the soil is led to losing moisture and becoming less acidic and fertile (Jinquan *et al.*, 2020). Globally, PFS contains more carbon than any other soil environment and surface soil layers of the PFS is the most dynamic part of soil organic matter (Arévalo-Gardini *et al.*, 2015). Based on the field surveys, most of the soil in the study area mainly includes sandy clay and clay loam and there is a low percentage of silt in them.

Studies on the PFOS provide useful information which can help to better understand soil resources for contributing to maintenance and development strategies of primary forests (Marty *et al.*, 2017; Dinh and Shima, 2022). Accordingly, deforestation for farming and other human activities leads to a decline in the vegetation cover, resulting in soil degradation by erosion processes especially in the slope topography areas (Amonum *et al.*, 2019). The sustainability of primary forest areas is, therefore, significantly influenced by soil quality.

This study was, therefore, focused to investigate the physiochemical features of soil within the primaeval forest area belongings to Thanh Chuong District in Nghe An Province, Vietnam to assess the fertility and productivity status of the soils.

MATERIALS AND METHODS

Study Area

The study area, primaeval forest area belongings to Thanh Chuong District in Nghe An Province, Vietnam lies within 18°34’42” N–18°53’33” N and 104°56’07” E–105°36’06” E, and covers an area of 1228 km^2, between the rivers on the west to north and southeastern (Fig. 1). The average altitude of the primaeval forest area is around 100 to 200 m above sea-level and its topography is diverse, complex and

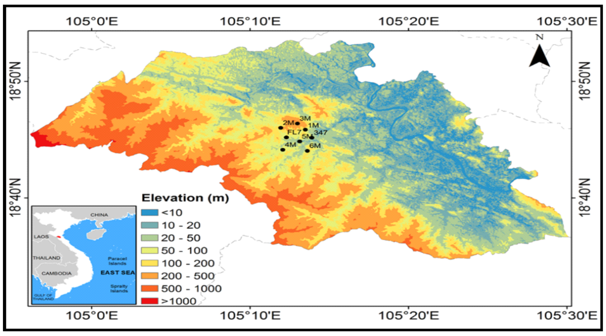

Fig. 1. Illustration of the study area with the surveyed locations marked with red circles.

divided by the system of hills. The study area has an average annual rainfall of approximately 2000 mm with a relative humidity of 80-90% while the average annual temperature is about 24-25°C and the maximum temperature is up to 40°C. (Fig. 2).

The total forest area of Thanh Chuong District accounts for 64.000 hectares in which natural forest is more than 41.000 ha, concentrated in 6 communes along the Vietnam-Laos border, including Thanh Son, Ngoc Lam, Thanh Thuy, and Thanh Ha. It is considered an area with many rare and precious timbers and great watershed protection value (Tue *et al.*, 2015).

Soil Sampling, Collection and Preparation

Ninety-six soil samples were collected randomly by hand from eight different survey locations across the study area (Fig. 1) at the four depths varying from 0-40 cm. All samples were taken into polythene bags and marked accordingly (Fig. 3). The samples were then, air dried, gently crushed and sieved through 2.0 mm mesh for laboratory analysis.

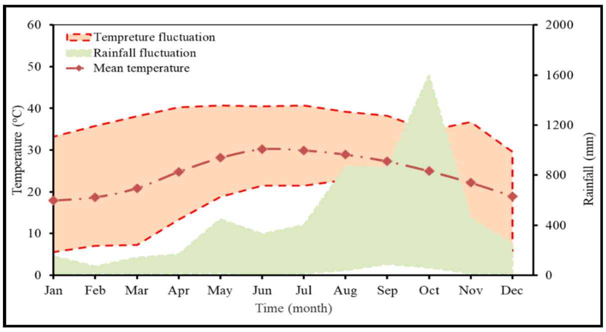

Fig. 2. Basic weather features across the study area from 1985 to 2019.

Laboratory Analysis

The laboratory analysis conducted on the soil samples included physical includes particle size (sand, silt and clay), BD and chemical analyses (pH, total carbon (TC), TN, TP, K^+, Ca^{2+}, and Mg^{2+}) (Fig. 4). Specifically, for physical analyses, particle size analysis was conducted sieving in combination with the hydrometer method of Brown (2009), the BD of the soils was defined by using the cylinder method (Carter and Gregorich, 2007), drying the undisturbed core samples to a constant weight at 105 °C, lasting 24 hours and dividing the oven-dried weight of the samples by its volume.

For chemical analyses, the pH of the soil samples was measured using an electrode pH meter (PCE-228) in water-soil solution (5:1) (Carter and Gregorich, 2007), the organic carbon contents of the soils and TN were obtained using C-N coder equipment while TP was measured by Olsen's sodium bicarbonate extraction method after ashing at 560 °C in 8 hours and dissolving with HCl 50% (Dinh and Sima, 2022). The ECs (K^+, Ca^{2+} and Mg^{2+}) were enucleated by applying a 1M ammonium acetate solution at rate 1:5 of soil: CH_3COONH_4 by the EDTA titration method. Total carbon and TN were obtained drying combustion using C-N analyzer CORDER MT–700, Yanaco, Japan. Analysis of K^+, Ca^{2+}, and Mg^{2+} was conducted using atomic absorption spectrophotometer (AA-6800).

Data Analysis

To determine the PFOS corresponding

Fig. 3. Field survey to collect soil samples a) take the soil samples, b) obtain samples and show in polythene bags and c) preserve samples.

Fig. 4. Illustrations of types of equipment for investigating PFOS a) equipment for sieving and heating samples EC-1200, b) equipment for soil sample analyses N-C coder, c) prepare samples and d) analysis atomic absorption spectrophotometer (AA-6800).

to different depth layers from the soil surface, the collected soil samples were subjected to descriptive statistics based on the one-way ANOVA method and Tukey HSD tests. In addition, the PFOS was also analyzed using Pearson correlation to show the relationship between the determined parameters.

RESULTS AND DISCUSSION

Physical Characteristics of the Soil Samples

Physical characteristics of the soil samples across the study area including soil texture (sandy, silt and clay) and BD were analyzed. The particle size characteristics were analyzed using the SO software (Dang, 2021). Texturally, the soil samples in the different depth layers across the study area are clay loam and sandy clay (Fig. 5). Quantitatively, results showed that clay encompassed highest percentage up to 59.06% while silt occupied the lowest percentage with an average rate of approximately 6.04%, and sand recorded an average rate of 32.32% (Table 1).

According to Arévalo-Gardini et al. (2015), the texture of the surface soil has great dominance in the development of soil aggregates. One of the key differences in the soil texture is the surface layers and it is one of the key reasons which dominates water potential, organic matter binding cation exchange as well other activities.

Chemical Features of the Soil Samples

For the pH of the soil samples, the results of the analysis showed that the pH at surveyed locations across the study area ranged from 3.75 to 4.85. Specifically, the soil samples at the FL7, 1M, 2M and 5M locations noted the pH increased with depth and the largest value up to 4.85 while at 2M, 3M, 4M, 6M, and 347 locations the pH values varying

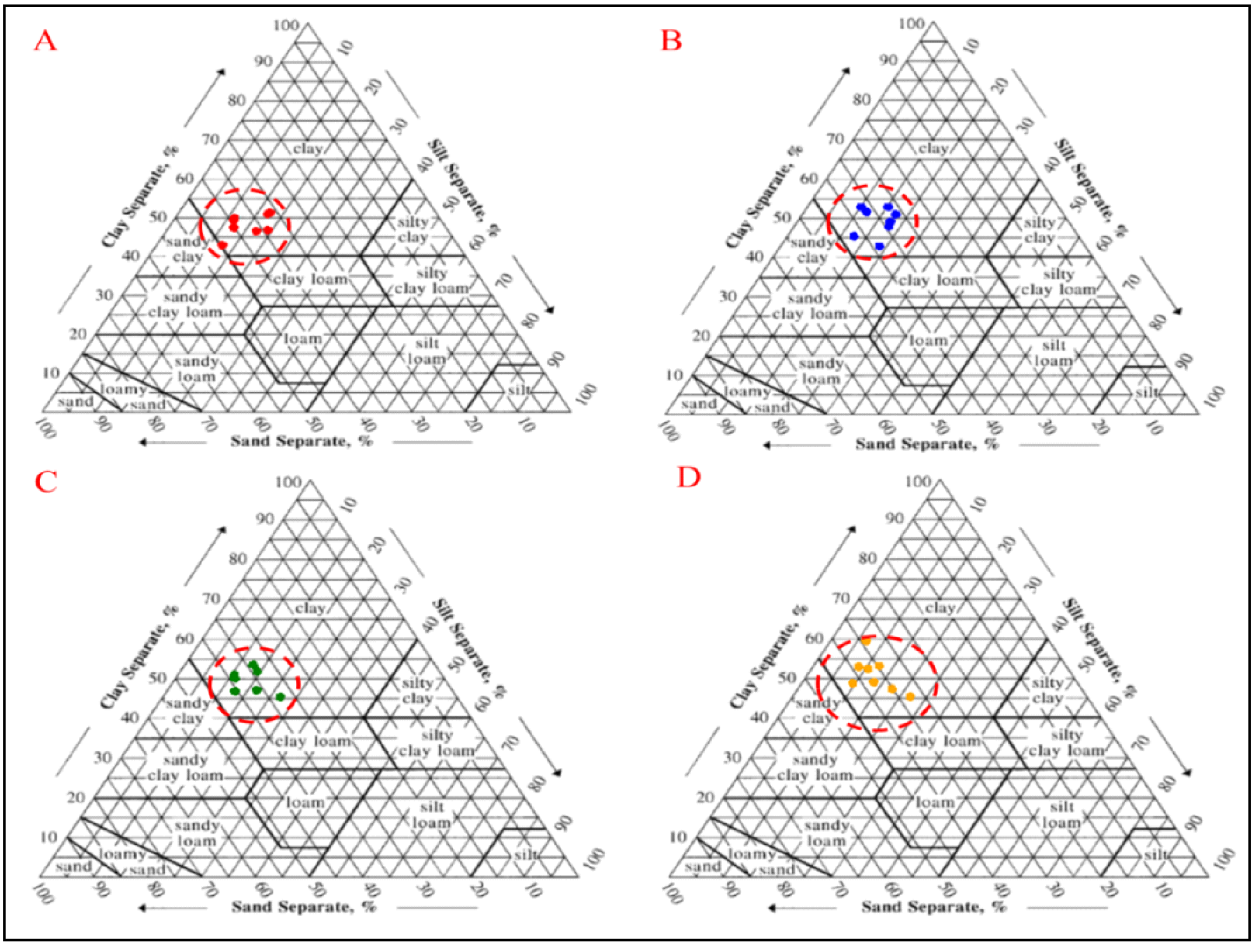

Fig. 5. Soil texture analysis results of soil samples based on the SO software at a) 0-5 cm depth layer, b) 5-10 cm depth layer, c) 10-20 cm depth layer, and d) 20-40 cm across the study area.

from 3.75 to 4.61. It means that the soil at the FL7, 1M, 2M and 5M locations are characterized as acidic in the depth layers from 0 to 20 cm while at depth layer from 20 to 40 cm, the soil is characterized as slightly acidic (Table 2). For 2M, 3M, 4M, 6M, and 347 locations the pH values are only characterized by acidic. According to Suleiman *et al.* (2017), the mildly acidic environment of soil will provide the best growing condition as well as suitable the uptake of nutrients by plants.

For total nitrogen (TN) content in the soils, results indicated that TN content in the soil samples across the study area varied from 0.95 to 2.66 g/kg while the values of TP and TC in the soil samples varied from 0.06 to 0.18 g/kg and from 6.13 to 29.21 g/kg, respectively (Table 2). According to Aliyu *et al.* (2016), Soil samples containing high carbon compounds are often very energy-rich, easily consumed by organisms, and quickly digested by soil microbes.

For exchangeable cations, analysis showed that the values of K^+, Ca^{2+}, and Mg^{2+} obtained 0.04-0.11, 0.03-0.26, and 0.03-0.15 Cmolc/kg, respectively (Table 2). Generally, the low values of exchangeable cations may be caused by soil nutrient losses through anthropogenic activities as well as cultivation, harvesting, slash-and-burn agriculture or climatic factors that can contribute to mobilization and immobilization of these cations. A study on the effects of slash-and-burn agriculture activities on the PFS in Prudentópolis municipality, southern Brazil by Thomaz *et al.* (2014) stated that the chemical properties of the soil were changer than the physical properties.

Correlation Analysis

Correlation analysis for all physicochemical parameters was conducted

Table 1. Physical features obtained the soil samples across the study area.

Position	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk density (g/cm)	Texture class
FL7	0-5	35.01	18.51	46.47	0.83	Sandy clay
	5-10	35.34	17.26	47.40	0.83	Sandy clay
	10-20	37.27	15.98	46.75	0.98	Sandy clay
	20-40	36.09	16.98	46.93	1.13	Clay loam
1M	0-5	32.32	15.73	50.95	1.04	Sandy clay
	5-10	32.93	14.67	52.40	1.09	Sandy clay
	10-20	34.86	13.79	51.35	1.09	Sandy clay
	20-40	35.60	11.70	52.70	1.33	Sandy clay
2M	0-5	33.22	16.48	50.30	0.98	Sandy clay
	5-10	33.07	16.65	50.53	1.12	Sandy clay
	10-20	32.51	17.00	50.50	1.02	Sandy clay
	20-40	33.70	21.26	45.05	1.24	Clay loam
3M	0-5	41.12	11.87	47.01	1.03	Sandy clay
	5-10	39.57	18.09	42.33	1.05	Sandy clay
	10-20	39.16	13.36	47.48	1.01	Clay loam
	20-40	38.65	13.04	48.32	1.14	Sandy clay
4M	0-5	39.78	10.72	49.50	1.03	Sandy clay
	5-10	37.62	11.19	51.19	1.11	Sandy clay
	10-20	39.80	10.55	49.65	1.01	Sandy clay
	20-40	38.04	9.96	52.00	1.12	Sandy clay
5M	0-5	40.21	10.71	49.02	1.24	Sandy clay
	5-10	38.04	9.56	52.40	1.41	Sandy clay
	40-20	39.49	9.96	50.55	1.40	Sandy clay
	20-40	39.57	7.93	52.50	1.34	Sandy clay
6M	0-5	45.56	11.85	42.58	1.06	Sandy clay
	5-10	43.10	11.97	44.93	1.14	Sandy clay
	10-20	41.43	12.08	46.49	1.22	Sandy clay
	20-40	42.70	8.85	48.45	1.32	Sandy clay
347	0-5	37.30	16.56	46.14	1.04	Sandy clay
	5-10	34.40	16.94	48.66	1.19	Sandy clay
	10-20	34.80	12.13	53.07	1.12	Sandy clay
	20-40	34.90	6.04	59.06	1.14	Clay loam
Min.		32.32	6.04	42.33	0.83	-
Mean		37.4	13.4	49.14	1.11	-
Max.		45.56	21.26	59.06	1.41	-

Table 2. Chemical features obtained the soil samples across the study area.

Position	Depth (cm)	pH	K+ (Cmolc/kg)	Ca2+ (Cmolc/kg)	Mg2+ (Cmolc/kg)	Total C (g/kg)	Total N (g/kg)	Total P (g/kg)
FL7	0-5	4.43	0.083	0.589	0.147	26.26	2.98	0.20
	5-10	4.35	0.080	0.192	0.079	22.06	2.63	0.18
	10-20	4.38	0.064	0.057	0.056	16.25	2.14	0.17
	20-40	4.59	0.055	0.025	0.031	10.74	1.60	0.15
1M	0-5	4.49	0.098	0.223	0.108	29.21	2.57	0.16
	5-10	4.56	0.075	0.095	0.078	23.42	2.29	0.13
	10-20	4.67	0.067	0.062	0.056	15.70	1.74	0.12
	20-40	4.82	0.051	0.036	0.026	6.53	1.00	0.09
2M	0-5	4.60	0.093	0.074	0.068	25.17	2.66	0.12
	5-10	4.57	0.076	0.092	0.067	24.32	2.65	0.07
	10-20	4.59	0.079	0.042	0.041	18.6	2.15	0.06
	20-40	4.61	0.053	0.031	0.025	12.71	1.67	0.11
3M	0-5	3.78	0.107	0.099	0.117	20.51	2.10	0.16
	5-10	3.90	0.094	0.094	0.097	21.57	2.16	0.18
	10-20	3.92	0.082	0.056	0.061	15.80	1.77	0.17
	20-40	3.75	0.062	0.041	0.041	10.78	1.08	0.14
4M	0-5	3.78	0.087	0.242	0.152	26.65	2.58	0.17
	5-10	3.83	0.088	0.151	0.111	17.04	1.94	0.15
	10-20	3.83	0.063	0.077	0.075	13.81	1.61	0.13
	20-40	3.97	0.054	0.047	0.043	10.26	1.26	0.08
5M	0-5	4.70	0.105	0.072	0.082	21.03	2.02	0.15
	5-10	4.85	0.081	0.037	0.058	13.96	1.46	0.13
	40-20	4.64	0.060	0.034	0.047	10.42	1.17	0.12
	20-40	4.85	0.074	0.030	0.026	7.79	0.95	0.11
6M	0-5	3.87	0.080	0.044	0.072	20.37	1.96	0.10
	5-10	3.96	0.061	0.038	0.053	14.85	1.71	0.10
	10-20	4.02	0.077	0.038	0.037	7.88	1.19	0.09
	20-40	3.97	0.058	0.032	0.030	6.13	1.02	0.07
347	0-5	3.99	0.056	0.255	0.130	17.78	1.94	0.18
	5-10	4.01	0.042	0.119	0.088	12.56	1.59	0.14
	10-20	3.85	0.044	0.110	0.064	11.61	1.50	0.15
	20-40	3.92	0.037	0.085	0.039	8.22	1.05	0.12
Min.		3.75	0.04	0.03	0.03	6.13	0.95	0.06
Mean		4.25	0.07	0.10	0.07	16.25	1.82	0.13
Max.		4.85	0.11	0.26	0.15	29.21	2.66	0.18

based on Pearson correlation with a confidence interval (p =95%). High correlation coefficients were obtained between silt with Ca (0.69), Mg (0.82), and TC (0.71) while moderately correlation coefficients also recorded K (0.68), TN (0.67) and TP (0.69). This implies that as the percentage of silt increases, the silt content and concentration of iron (K^{+}, Ca^{2+} and Mg^{2+}) with TN and TP in the soil samples across the study area also increase. Contrary, negative correlation coefficients were also defined between silt and clay (-0.29) with BD (-0.54) (Table 3).

Contrary, negative correlation coefficients existed between sand with silt (-0.93), clay (-0.08), Ca (-0.73), K (-0.71), Mg (-0.67), TC (-0.66), TN (-0.63) and TP (-0.59). While positive correlation coefficients were obtained between sand and BD (0.58) with pH (0.01). A significantly positive correlation was observed between silt and bulk density (0.58), organic carbon (0.56) and organic matter content (0.55). For clay, negative correlation coefficients varying from -0.52 to -0.04 recorded all other physical and chemical parameters.

Bulk density was moderate to highly negative correlation coefficients (from -0.98 to -0.73) with all remaining parameters, except for a positive correlation coefficient with pH (0.81). pH soil was strong to moderately positive correlation coefficients (from -0.68 to -0.25) with TN, TP, and ECs while TC had strongly a positive correlation coefficient with TN and TP. The level of soil pH strongly influences soil processes such as nitrogen cycling by dominating the PFOS and biological processes (Anderson *et al.*, 2017).

CONCLUSION

The study investigated the physicochemical features of soil across the

Table 3. Pearson Correlation coefficients of the determined parameters in the soil samples

Parametes	Depth	Sand	Silt	Clay	BD	pH	Ca	K	Mg	TC	TN	TP
Depth	1											
Sand	0.67	1										
Silt	-0.73	-0.93	1									
Clay	0.24	-0.08	-0.29	1								
BD	0.94	0.58	-0.54	-0.04	1							
pH	0.62	0.01	0.06	-0.22	0.81	1						
Ca	-0.91	-0.73	0.89	-0.51	-0.73	-0.25	1					
K	-0.97*	-0.71	0.68	-0.01	-0.98*	-0.68	0.82	1				
Mg	-0.96*	-0.67	0.82	-0.47	-0.82	-0.41	0.99*	0.88	1			
TC	-1**	-0.66	0.71	-0.18	-0.96*	-0.66	0.88	0.98*	0.94	1		
TN	-1**	-0.63	0.67	-0.17	-0.97*	-0.68	0.87	0.98*	0.93	1***	1	
TP	-0.99**	-0.59	0.69	-0.34	-0.92	-0.62	0.91	0.94	0.97*	0.99*	0.99*	1

Correlation is significant at p ? 0.05, values with * are values for significant pair. While BD is bulk density; TC is total carbon; TN is total nitrogen and TP is total phosphorus.

study area to assess the fertility and productivity status of the soils. Results show that the soil texture across the study area mainly included clay loam to sandy clay and the key chemical characteristic of the soil varied from acidic to slightly acidic. Based on the findings, the variation in the texture of silt content among the depth layers of soil is minimal. In general, the physicochemical features of soil were the main dominant factors influencing the extent of the decomposition process. The primaeval forest serves as protection for the soil as well as promoting the fertility and productivity of the soils to maintain flourishing vegetation types.

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