INTRODUCTION

Tropical rainforest especially in Malaysia is considered the richest and one of the most complex ecosystems in terms of structure and species that exist among the ecosystems on earth (Zakaria, Rajpar, Ozdemir, & Rosli, 2016). In Peninsular Malaysia, it is generally dominated by dipterocarp forests which are considered an important type of forest because they consist of many timber trees that have high economic value (Appanah & Weinland, 1993; Sadeghi, Faridah-Hanum, Wan Razali, Abd Kudus, & Hakeem, 2014). Nowadays, tropical rainforests in Malaysia have been disrupted by human activities, such as the conversion of forests to oil palm or rubber plantations, excessive deforestation, which can lead to forest land degradation. Perumal, Wasli, Ying, Lat, & Sani (2015) stated there are also commercial logging activities on timber trees, cultivation changes, industrial urbanization, and natural disturbances such as landslides caused by deforestation. Degradation in the tropical rainforest has reached a threshold and rehabilitation is a critical subject of worldwide foresters, pedologists, and ecologists. Montagnini, Eibl, Grance, Maiocco, & Nozzi (1997) stated that the conversion of forest areas to non-

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ABSTRACT

The influence of topography on soil morphology, classification and characteristic is poorly understood in Ayer Hitam Forest Reserve, Malaysia. Topographic vegetation-soil interrelations are important because the existing plants are used to indicate environmental conditions and potential forest productivity. This study aims to identify the effect of toposequence on soil morphology, soil classification, soil characteristic and forest vegetation. Five plots surveyed on 100-150 cm soil profile depth to identify soil development, soil classification and nutrient status (i.e. organic matter, Al, pH, K, Na, Ca, Mg, CEC, Base Saturation). Besides, the distribution of forest vegetation serve as the basis to evaluate the trees’ basal area and diversity. Soil subgroups ranged from Fragic Hapludults in the ridge, Typic Hapludults and Plintic Hapludults on the middle slope, Typic Hapludults on the lower slope, and Typic Hapludults in footslope. Each soil subgroup has its characteristics at various elevations (Morphology and Physio-chemical). Vegetation on each plot was dominated by species of Euphorbiaceae, Myrtaceae, Dipterocarpaceae Malvaceae, Moraceae, Verbenaceae, Phylanthaceae, and Santalaceae.
forest land such as agricultural land results in a permanent reduction of native species including wood species such as *Dipterocarpus* spp.

Topographic plant-soil interrelations are important because the vegetation is increasingly being used to indicate environmental conditions and potential forest productivity (Fisher & Binkley, 2000). Soil plays a vital role in forest development. They provide water, nutrition, and support for trees and other forest vegetation. Soil comes from parent materials with different materials, and these produce different soil properties so that it can affect both the forest composition and its growth rate. However, comprehensive researches on the influence of topography and vegetation on the development and classification of soils in the Peninsular Malaysian was still limited, especially the Ayer Hitam Forest Reserve. Information on soil characteristics and morphological properties can be determined by observing soil profiles. In general, the morphological nature of soils with their shape and composition can be observed through field surveys and laboratory analysis. The study aims to identify the effect of topography on soil morphology, classification, characteristic and forest composition according to toposequence in Ayer Hitam, The results of this study serve as basic information for optimal use of forests such as conservation strategies and rehabilitation of forest land. This research was conducted in the forest owned by Universiti Putra Malaysia, namely Sultan Idris Shah Forest Education Center (SISFEC) or better known as Ayer Hitam Forest Reserve, Selangor, Peninsular Malaysia.

**MATERIALS AND METHODS**

**Description of Study Sites**

This research was carried out in the Ayer Hitam Forest Reserve or Sultan Idris Shah Forest Education Center (SISFEC) according to Figure 1 which is administratively located in the Bandar Bukit Saujana Puchong, Selangor Darul Ehsan, Peninsular Malaysia. The study site was located at 2°56' - 3°16'N and 101°30' - 101°46'E and was 20 km from Universiti Putra Malaysia and 45 km from Kuala Lumpur. SISFEC located at the hearth of a fast developing area Puchong, it is flanked by the administrative capital, Putrajaya, Bandar Kinrara towards the north, Bandar Puteri lies to its west and Taman Desaminium in the east. Close at hand in the south lies the Federal Territory of Putrajaya. Ayer Hitam Forest Reserve has an area of 1248 hectares. The minimum and maximum temperature in Ayer Hitam Forest Reserve is 22.7 dan 32.1°C, respectively while the daily average temperature is 26.6°C. The minimum and maximum relative humidity is 59 and 96%, respectively while, the average relative humidity is recorded at 83% (Bawon, 2007). The elevation of Ayer Hitam Forest Reserve ranges from 15 to 233 masl with the highest area is Bukit Permatang Klang. The overall landscape of Ayer Hitam Forest Reserve is rugged and hilly. Rasau River in the south and Bohon River in the north are the main sources of irrigation in the forest. Ayer Hitam Forest Reserve is formed from rock with granite as the main component. The main parent material in the soil shows metamorphic content and secondary minerals ferromagnesium (Bawon, 2007).

**Soil Sampling**

Soil sampling was conducted in October 2018 to April 2019 in Ayer Hitam Forest Reserve. A total of five soil pits were dug. Soil samples were collected at the following depths; 0-20, 20-40, 40-60, 60-80, 80-100, 100-120, and 120-150 cm for each soil pit. In addition, the soil profiles were also characterized based on the soil horizons. Following the Table 1, the pits were grouped into three sub landforms, i.e. located at hill slope (P₁ and P₂), at medium slope (P₃ and P₄) and at lower slope (P₅).

| Location | Landform          | Coordinate                  | Parent Material               |
|----------|-------------------|-----------------------------|------------------------------|
| P₁       | Top               | 101°38'19 - 253'E and 3°0'46 - 301'N | Igneous rock and granite     |
| P₂       | Upper middle slope| 101°38'25 - 619'E and 3°0'41 - 79'N | Igneous rock and granite     |
| P₃       | Lower middle slope| 101°38'30 - 24'E and 3°0'37 - 986'N | Igneous rock and granite     |
| P₄       | Lower slope       | 101°38'33 - 731'E and 3°0'35 - 125'N | Igneous rock and granite     |
| P₅       | Foot slope        | 101°38'37 - 324'E and 3°0'32 - 356'N | Igneous rock and granite     |

**Table 1. Location of the soil profile in Ayer Hitam Forest Reserve**
Vegetation analysis was selected from 5 plots measuring 20 x 20 m. Measurement of vegetation was carried out to all trees that have > 12 cm dbh (diameter at breast height) (dbh 1.3 m above ground) and are representative for the areas of the top, upper middle slope, lower-middle slope, lower slope, and foot slope.
**Laboratory Analysis**

Soil physical and chemical properties were analyzed following USDA methods from Soil Survey Staff (2011). Bulk density was measured using the coring method from Blake & Hartge (1986). Soil particle size distribution was measured using pippete method from Kilmer & Alexander (1949) to determine size particle and percentage of clay, silt and sand compositions within the soil. Soil pH was measured using soil-water and soil-KCL solution mixtures in a ratio of 1:1. Organic matter was determined by loss on ignition (LOI) method by Davies (1974). K, Na, Ca, M were extracted using 1 M ammonium acetate (pH 7.0) and measured by atomic absorption spectrophotometry using method from Wright & Stuczynski (1996). Al and H were extracted by 1 M KCL suspension, total carbon and total nitrogen were measured by CNS analyzer (TruMac Methodology Ver 1.1x). Available P was measured by the Bray method Bray & Kurtz (1945).

**Statistical Analysis**

Canonical Variate Analysis (CVA) was used to study relationship between the parameters of soil chemical properties and the relationship between parameters vegetation and topography. Genstat 19th Edition (VSNI UK) was used to conduct CVA.

### Table 2. Soil morphology in Ayer Hitam Forest Reserve

| Profile | Symbol | Depth  | Colour  | Structure | Consistency |
|---------|--------|--------|---------|-----------|-------------|
|         |        |        | Moist   | Dry       |             |
|         |        |        |         | sbk, m, m |             |
|         |        |        |         | fi        |             |
|         |        |        |         | vfi       |             |
|         |        |        |         | npl       |             |
|         |        |        |         | spl       |             |
|         |        |        |         | pl        |             |
|         |        |        |         | nst       |             |
|         |        |        |         | sst       |             |
|         |        |        |         | spl       |             |
|         |        |        |         | vha       |             |
|         |        |        |         | vha       |             |
|         |        |        |         | eha       |             |
|         |        |        |         | shka      |             |
|         |        |        |         | lo        |             |
|         |        |        |         | so        |             |
|         |        |        |         | sbk       |             |
|         |        |        |         | abk       |             |
|         |        |        |         | f         |             |
|         |        |        |         | w         |             |
|         |        |        |         | subangular blocky |         |
|         |        |        |         | angular blocky |         |
|         |        |        |         | medium |             |
|         |        |        |         | coarse |             |
|         |        |        |         | fine |             |
|         |        |        |         | weak |             |
|         |        |        |         | moderate |             |
|         |        |        |         | strong |             |

Remarks: fr=friable; fi=firm; vfi=extremely firm; npl=non plastic; spl=slightly plastic; pl=plastic; nst=non sticky; sst=slightly sticky; st=sticky; ha=hard; vha=very hard; eha=extremely hard; lo=loose; so=soft; sbk=subangular blocky; abk=angular blocky; md=medium; c=coarse; f=fine; w=weak; mr=moderate; s=strong
| Plot | Depth | Texture | BD | pH | OM | K | Na | Ca | Mg | Al | H | ECEC | CEC | BS | Al Sat | Av. P |
|------|-------|---------|----|----|----|---|----|----|----|----|----|-----|-----|----|--------|-------|
| P1   | 0-10  | 34      | 14 | 52 | 1.22 | 3.99 | 4.26 | 7.00 | 0.02 | 0.05 | 0.07 | 0.08 | 0.28 | 0.89 | 0.50 | 5.24 | 4.20 | 56.00 | 16.20 |
|      | 10-15 | 40      | 10 | 50 | 1.30 | 4.06 | 4.32 | 6.79 | 0.02 | 0.03 | 0.08 | 0.03 | 0.25 | 0.76 | 0.41 | 4.68 | 3.42 | 60.98 | 14.70 |
|      | 15-50 | 80      | 18 | 2  | 1.67 | 4.08 | 4.35 | 6.42 | 0.01 | 0.02 | 0.08 | 0.01 | 0.25 | 0.64 | 0.37 | 1.77 | 6.78 | 67.57 | 11.30 |
|      | 50-110| 81      | 14 | 5  | -    | 4.01 | 4.31 | 6.59 | 0.01 | 0.01 | 0.06 | 0.02 | 0.18 | 0.58 | 0.28 | 1.09 | 9.17 | 64.29 | 9.60  |
| P2   | 0-5   | 40      | 40 | 20 | 1.25 | 3.94 | 4.22 | 7.07 | 0.03 | 0.03 | 0.12 | 0.11 | 0.38 | 0.42 | 0.67 | 3.09 | 9.39 | 56.72 | 23.50 |
|      | 5-15  | 40      | 60 | 0  | 1.42 | 4.07 | 4.35 | 7.00 | 0.02 | 0.03 | 0.04 | 0.01 | 0.38 | 0.36 | 0.48 | 1.34 | 7.46 | 79.17 | 23.20 |
|      | 15-60 | 40      | 40 | 20 | -    | 4.20 | 4.49 | 6.97 | 0.01 | 0.03 | 0.04 | 0.02 | 0.12 | 0.32 | 0.22 | 1.39 | 7.19 | 54.55 | 19.70 |
|      | 60-150| 40      | 40 | 20 | -    | 4.20 | 4.54 | 6.55 | 0.01 | 0.02 | 0.12 | 0.02 | 0.1 | 0.27 | 0.27 | 1.48 | 11.49 | 37.04 | 19.50 |
| P3   | 0-5   | 40      | 40 | 20 | 1.27 | 4.13 | 4.56 | 7.03 | 0.02 | 0.05 | 0.06 | 0.05 | 0.25 | 0.42 | 0.43 | 14.78 | 1.22 | 58.14 | 18.70 |
|      | 5-35  | 60      | 30 | 10 | 1.30 | 4.13 | 4.43 | 6.73 | 0.02 | 0.02 | 0.06 | 0.02 | 0.25 | 0.36 | 0.37 | 1.58 | 7.59 | 67.57 | 18.20 |
|      | 35-70 | 60      | 20 | 20 | 1.38 | 4.19 | 4.45 | 6.38 | 0.02 | 0.02 | 0.06 | 0.02 | 0.25 | 0.32 | 0.37 | 1.48 | 8.11 | 67.57 | 16.60 |
|      | 70-100| 80      | 20 | 0  | -    | 4.2  | 4.46 | 5.96 | 0.01 | 0.04 | 0.03 | 0.06 | 0.18 | 0.27 | 0.32 | 1.41 | 9.93 | 56.25 | 16.19 |
|      | 100-150| 80     | 20 | 0  | -    | 4.25 | 4.49 | 5.53 | 0.01 | 0.04 | 0.01 | 0.08 | 0.18 | 0.24 | 0.32 | 1.27 | 11.02 | 56.25 | 14.50 |
| P4   | 0-27  | 40      | 20 | 40 | 1.20 | 4.27 | 4.42 | 6.79 | 0.03 | 0.04 | 0.07 | 0.04 | 0.44 | 0.54 | 0.62 | 7.21 | 2.50 | 70.97 | 25.40 |
|      | 27-60 | 40      | 0  | 60 | 1.30 | 4.31 | 4.43 | 6.55 | 0.03 | 0.02 | 0.02 | 0.01 | 0.23 | 0.47 | 0.31 | 6.44 | 1.24 | 74.19 | 25.10 |
|      | 60-95 | 40      | 10 | 50 | -    | 4.34 | 4.45 | 6.38 | 0.02 | 0.02 | 0.01 | 0.01 | 0.23 | 0.36 | 0.29 | 5.61 | 1.07 | 79.31 | 19.60 |
|      | 95-125| 41      | 7  | 52 | -    | 4.35 | 4.46 | 6.21 | 0.01 | 0.02 | 0.07 | 0.01 | 0.15 | 0.31 | 0.26 | 5.03 | 2.19 | 57.69 | 19.40 |
|      | 125-170| 60    | 20 | 20 | 4.35 | 4.49 | 5.51 | 0.01 | 0.01 | 0.06 | 0.01 | 0.11 | 0.24 | 0.2 | 4.67 | 1.93 | 55.00 | 18.80 |
| P5   | 0-10  | 0      | 40 | 60 | 1.27 | 4.14 | 4.26 | 7.00 | 0.05 | 0.09 | 0.02 | 0.11 | 0.32 | 0.34 | 0.59 | 11.57 | 2.33 | 54.24 | 20.70 |
|      | 10-30 | 40      | 0  | 60 | 1.34 | 4.19 | 4.38 | 6.59 | 0.06 | 0.06 | 0.03 | 0.1 | 0.3 | 0.25 | 0.55 | 8.57 | 2.92 | 54.55 | 20.50 |
|      | 30-70 | 40      | 20 | 40 | 1.38 | 4.3 | 4.47 | 6.38 | 0.06 | 0.01 | 0.01 | 0.17 | 0.3 | 0.21 | 0.55 | 8.42 | 2.97 | 54.55 | 20.20 |
|      | 70-100| 40      | 40 | 20 | -    | 4.33 | 4.5 | 6.34 | 0.01 | 0.02 | 0.00 | 0.01 | 0.25 | 0.17 | 0.44 | 2.15 | 1.86 | 56.82 | 18.60 |
|      | 100-130| 80   | 20 | 0  | -    | 4.35 | 4.53 | 6.13 | 0.01 | 0.01 | 0.01 | 0.22 | 0.11 | 0.26 | 2.17 | 1.84 | 84.62 | 18.40 |

Remarks: *bulk density; °organic matter; °total carbon; °total nitrogen; °sum of effective cation capacity K+Na+Ca+Mg+Al; °cation exchange capacity; °sum of base saturation total base/CEC×100%; °Al saturation Al/CEC×100%; °available P.
RESULTS AND DISCUSSION

Soil Morphological Characteristic in Ayer Hitam Forest Reserve

Generally with a following at the Table 2, the soil color of Ultisol is brownish yellow to red. The soil in Ayer Hitam Forest Reserve develops from metamorphic rock and granite, with dominant forest vegetation. The darker color at the horizon A and AB suggests a sufficient duration to accumulate soil organic matter (Abdu et al., 2007). Hattori et al. (2005) stated that the accumulation of organic matter is found to be very high on the surface horizon of forests compared to degraded land in Sarawak, Malaysia. Then in the subsoil layer (60-100) in each soil profile P1, to P5, there is a Bt horizon. Bt horizon indicates an accumulation of silicate clay. The symbol *t* indicates the presence of silicate clay deposition, caused by the illuviation process of the surface horizon (Soil Survey Staff, 2014). Ultisols are defined as soil that has an argillic horizon (Bt) in the subsoil (Soil Survey Staff, 2014). Jusop & Ishak (2010) and Tessins & Shamsuddin (1983) states that the clay resulted from illuviation process will move from topsoil and accumulate in horizon B under a tropical environment that has a leaching intensity. There is no doubt one of the minerals in the clay fraction is kaolinite.

Each soil profile found in P1 through P5 has a pile of organic material with different thickness which is brownish-black (10 YR 3 / 1-10 YR 5/3). The increasing soil depth (subsoil) has undergone brownification from yellowish-brown to redder brown-orange (7.5 YR 4/6 to 10 YR 8/8). Markley (2017) stated that the browner the color of the soil generally indicates the high content of goethite, and the redder the soil color indicate the higher the content of hematite in the soil. One study by Tessins & Shamsuddin (1983) stated that Kaolinite is the most important mineral that makes the yellowish color on Ultisols in Malaysia.

Overall the soil at the study sites P1 through P5 has structure development from weak to strong levels. As the depth profile increases, the level of structural development also increase. The topsoil layer is dominated by organic matter and has a fine granular structure to subangular blocky with a weak developmental level. The subsoil layer is dominated by subangular blocky to angular blocky structures with medium to coarse size and has a strong level of development. In general Ultisol soil structures have moderate to strong structures, with subangular blocky (Fauzi, Zauyah, & Stoops, 2004; Prasetyo & Suriadiakarta, 2006; Prasetyo, Subardja, & Kaslan, 2005). The consistency of the Ayer Hitam Forest Reserve as a whole the top surface of profiles P1 through P5 has a moist consistency with a level of friable to slightly friable. Wet consistency is not sticky - slightly sticky and not plastic to slightly plastic. Subsoil consistency increases with moist conditions up to very firm and wet conditions induce slightly plastic and slightly sticky. Changes in the level of consistency of plastic wet and sticky indicate that the soil is dominated by clay texture.

Soil Physio-Chemical Properties in Ayer Hitam Forest Reserve

The texture composition of the soil on the study sites was affected by weathering processes of the parent material. The soils at both sites can be divided into two texture classes based on the composition of clay and sand fractions. The clay content in Ayer Hitam Forest Reserve was more than 40% in subsoil (horizon B). While the sand content was more than 20% in topsoil (horizon A). In the case of Ayer Hitam Forest Reserve with high clay content on subsoil, these may be due to the weathering and the illuviation processes caused by high rainfall at this sites. Since patchy cutans were found in the subsoil at these sites, a significant increase of clay contents with depth by illuviation was promoted by rainwater (Hattori et al., 2005). Prasetyo & Suriadiakarta (2006) states that the mineral composition of soil parent material can affect soil texture. Parent materials dominated by weathered quartz resistant minerals, such as granite and sandstone, tend to have a rough texture.

Some studies by Abdu et al. (2010) indicates the high sand content in Bidor and Kinta Forest is related to sandy material in surface soil, which granite wash has been deposited a long time ago. According the Table 3 pH values range between 3.94 and 4.35 which indicates the soil in the Ayer Hitam Forest Reserve is acid.

The study site in the Ayer Hitam Forest Reserve has high to moderate organic matter content, ranges from 7.07-5.31% in the surface layer (horizon A) and decreases along with the soil depth. Several studies indicated that forest organic matter in Malaysia ranged between 6.06–16.63% (Akbar et al., 2010; Karam, Abdu, Rajoo, Jamaluddin, & Karim, 2017; Karam et al., 2012; Khairil, Wan Juliana, Nizam, & Razi Idris, 2014; Nik Norafida, Nizam, Wan Juliana, & Faezah, 2018).
Fig. 2. Variation with the depth soil chemical properties for five plots located in the different topographic positions.
The cations exchange (K, Na, Ca, Mg) was found varied at each horizon in each soil profile (Table 3). Table 3 shows that almost all surface horizons on the slopes of the ridge to the lower Ayer Hitam Forest Reserve have low Potassium (K) values (0.05–0.02 cmol/kg) (Figure 2) and decreases with soil depth (0.02–0.01 cmol/kg). At the Figure 2 shows Natrum (Na) values in all soil profiles P1 to P5 are low from all soil depths (0.09–0.01 cmol/kg). The highest value of Ca in the soil profile is in the topsoil on P1 and P4 with the values of (0.12 and 0.02 cmol/kg). However, P4, P5, and P6 profiles have the same relative Ca value in horizon A to the highest horizon B that ranges between (0.06–0.07 cmol/kg) and the lowest is 0.08–0.00 cmol/kg. Magnesium (Mg) at the study site on each soil profile of each slope also varies in value. The highest value is in P1 and P5 with the value of 0.11–0.00 cmol/kg and P1, P5, and P6 have the highest value (0.02–0.05 cmol/kg) each of the values mentioned is on horizon A. The lowest value of Mg on each slope P1 to P5 is on horizon B with values varying between 0.01–0.08 cmol/kg. Soils at the study site have very high to low CEC with the value of up to 14.78–1.09 cmol/kg in overall soil profile P1 to P5. At ground level, it has a low CEC value ranging between 5.17–1.09 cmol/kg.

The exchangeable values of Al and H are very high on the surface. However, they decrease with increasing soil depth on each slope P1 to P5. High Al values range from 0.44–0.28 cmol/kg surface and decrease in horizon B with values ranging between 0.22–0.10 cmol/kg (Figure 2). The highest value of H content is also observed in horizon A which ranges from 0.34 to 0.89 cmol/kg, while the value of horizon B ranges from 0.11 to 0.58 cmol/kg (Figure 2). The base saturation value at the study site varies from low to very low (11.02–0.64%) in each soil profile P1 to P5 on each slope on Ayer Hitam Forest Reserve. The content of available P is found high on horizon A and decreases with increasing depth. Highest to lowest available P at the P1, and P5, horizons on each slope is 25.40–9.60 Mg P/kg. The total carbon and nitrogen in P1 to P5 is low, total carbon from high to low ranges 2.56–0.01%, while total nitrogen varies from high to low at 0.50–0.01%. Each total carbon and nitrogen are high at the surface and decreases with the increasing depth of the soil.

Soil Chemical Characteristic in Ayer Hitam Forest Reserve

According to the results of soil chemical analysis of the profile samples, the soil in the study sites could be characterized to be an acidity with a lower content of an exchangeable cations (K, Na, Ca, and Mg). The soil parent material of Ayer Hitam Forest Reserve was highly exposed to sunlight and highly weathered. This characteristic shows that the soil classification on the P1–P5 are Ultisols. Jusop & Ishak (2010) state that pH Ultisols soil in Malaysia ranges from 4 to 5 with lower pH for the more weathered one. The low pH on the surface can be related to the high amount of organic matter on the surface. The high value of surface organic matter is responsible for soil acidity through litter decomposition. The higher pH value in the subsoil is due to the reduced value of organic matter. Studied in Bidor and Kinta forests Malaysia (Zaidey et al., 2010), stated that the lower pH values at the layer across the study sites were relate to the larger amounts of organic matter in the topsoil, reflecting the organic matter is responsible for acidity through litter decomposition. Kadir et al. (2001) reported that high acidity at the soil surface has been associated with the hydrolysis of Al, caused by very high leaching cation and then lowering the pH of the soil which can cause toxicity. The increase of soil acidity and soil depth can be related to Fe and Al oxides which is also characterized by high organic matter and low pH. Tonon et al. (2010) states that the level of organic matter decomposition depends on soil pH. Akhtaruzzaman, Haque, & Osman (2014) also state that higher CEC in surface soil might be due to a higher amount of organic carbon in surface layers CEC content might be related to the soil texture, clay mineralogical composition, and accumulation of organic matter and degree of erosion. Several studies have found that the negative charge comes from clay minerals which affect CEC (Akhtaruzzaman, Haque, & Osman, 2014; Ohta & Effendi, 1992; Perumal, Wasli, Ying, Lat, & Sani, 2015; Sakurai, Tanaka, Ishiduka, & Kanzaki, 1998; Tanaka et al., 2007). The content of available P is found to be high at the horizon A and decreases with the increase of soil depth.

The results of the study in Ayer Hitam Forest Reserve show a pH value ranging from 4 to 5, which may indicate that P fixation in the soil is dominated by aluminum. Jusop & Ishak (2010) and Karam, Abdu, Rajoo, Jamaluddin, & Karim (2017) explained that negatively charged phosphorus tends to be strongly bound to aluminum and iron which are mostly found in decaying soil, one of them is Ultisols and Oxisols.
Soils Classification and Development

Five soils sampled within the toposequence were classified into the same order and less different in a subgroup. Ayer Hitam Forest Reserve has a soil moisture regime of Udic with temperature regime of Isohypertermic, typical soil in well-drained areas of the tropical region. Soil profiles P1 through P5 were developed from metamorphic rocks and granite which have a clay content at a depth of 60-150 cm.

The soil surface has a calcic saturation of less than 50% so it can be categorized as Umbic (Soil Survey Staff, 2014). Endopedon soil profiles P1 and P2 have fragipan properties. However, P4 profile has plinthite characteristics. According to Rayes (2017) plinthite is characterized by weathered clay which is rich in sesquioxide with poor humus, shaped polygonal to resemble large rusts of red color; solidify or switch irreversibly to concrete in wet and dry conditions. All subsoil profiles P2 through P5 have evidences of clay illuviation so that they are categorized as argillic horizons (Soil Survey Staff, 2014). Prasetyo & Suriadikarta (2006) states that argillic horizons are generally rich in Al so that they are sensitive to plant root development. The roots were usually not able to penetrate this horizon and develop only above the argillic horizons. This phenomenon always occurs in the subsoil layer of Ultisols in Peninsular Malaysia (Jusop & Ishak, 2010). In this study, the clay fraction analysis was not carried out so that it cannot be categorized as the Kandic horizon. Profile P1 has a subgroup of Fragic Fragiuultds soil. P2 soil profile has fragile and plinthite characteristics categorized as Plintic Fragiudults. Profile P3, P4, and P5 do not have other characteristics so that the subgroup is categorized as Typic Hapludults (Soil Survey Staff, 2014). The overall soil profile is categorized as the Ultisols soil order.

Forest Composition in Ayer Hitam Forest Reserve

The overstory composition in each P1 to P5 is strongly associated with topography. Fig. 3a shows that P1 has a large variety of tree species like Sapium baccatum Roxb., Endospermum diadenum, Palaquium maingayi, Pentace hassk, Scaphium longiflorum, Shorea parvifolia, Trebelus elongatus, Vitax pubescens, Aporusa symplocioides, Scleropyrum watchianuni. With a basal area of 30.57 m2/ha (Fig. 3b). The forest has an index value of 48.15% (Fig. 3d). The average tree height in plot 1 were > 13.4 m. P2 has a basal area of 22.53 m2/ha (Fig. 3b). The most important tree species (Fig. 3a) in this area are Endospermum diadenum, Hopea sulcata, Shorea acuminata, Shorea leprosula, Elaeocarpus sp. Meranti tree (Shorea sp.) has an index value of 90.35% (Fig. 3d). The value is higher than P1. This is because P1 has more varied species compared to P2. P3 and P4 that had the lowest basal area compared to other plot areas with a basal area of P3 area of 13.80 and P4 of 7.49 m2/ha (Fig. 3b).

P3 has a variety of tree species, namely Shorea parvifolia Dyer, Shorea sp., Elaeocarpus sp., Coelostegia griffithii, Dipterocarpus costulatus V. SI, Shorea macroptera Dyer, Dyera costulata. P3 has an index value of 49.12% (Fig. 3d). P4 dominated with Tempinis trees (Trebelus elongatus, Endospermum diadenum, Rtocarpus interger Var. Cyathocalyx tree, Dipterocarpus crinitus). P4 has an index value of 99.90% (Fig. 3d). Area P4 has the highest index value in the Ayer Hitam Forest Reserve. P5 has a basal area of 24.29 m2/ha (Fig. 3b) with an important index value of 74.45%. The area is dominated by broadleaf medang trees (Litsea grandis Hk. F.) with a variety of tree species including Endospermum diadenum, Lithocarpus, Shorea platycarpa Heim, Litsea grandis Hk. F., Melanorrhoea spp., Castanopsis motleyana. Fig. 3e shows Diversity index values (Shannon and Weiner) in the Ayer Hitam Forest and are categorized as moderate. Ayer Hitam Forest Reserve has a high index of richness and evenness (Fig. 3f and 3g). A diversity index is important information about a community, the wider the sample area, the more species are found (Mougi & Kondoh, 2012). Saridan (2012) stated that high diversity is a stable growth Areas in the form of secondary forest. This research in line with the statement of Naidu & Kumar (2016) who states that high diversity can show communities that have high complexity. Likewise with the community, there is high interaction because it involves energy transfer and niche distribution competition which is theoretically more complex.

It can be seen that Ayer Hitam Forest Reserve has several Regions in the form of secondary forest. This allows the diversity index values at these sites to be moderate. Sasaki & Laenenoth (2011) states that if a community is composed of a few types and only a few species are dominant, then the value of diversity is low. Medium diversity index values can show communities that have low complexity and community interaction between types. This research in line with the statement of Naidu & Kumar (2016) who states that high diversity can show communities that have high complexity. Likewise with the community, there is high interaction because it involves energy transfer and niche distribution competition which is theoretically more complex.
Fig. 3. Vegetation composition on different topography: a) Tree species, b) Basal area, c) Tree density, d) Index Importance value, e) $H'$ index, f) Richness index, g) Index of evenness
Soil Properties towards Topography and Forest Vegetation in Ayer Hitam Forest Reserve

Topography and soil parent material are factors that influence soil formation at the study site. The level of soil development at the research location can be observed from the thickness of the horizon, color, chemical, and physical properties of the soil. The topography in the Ayer Hitam Forest Reserve is categorized as a low dipterocarp forest, which has an elevation of 233 masl. Point P₁, which is the highest (Permatang Kuang) point in the Ayer Hitam Forest Reserve has shallow soil depth < 110 cm with fragipan on the subsoil. According to Bockheim & Hartemink (2013) P₂ until P₅ has a deep soil solum (> 120 cm). The deep soil solum at this point might be due to sedimentation. The soil in position P₅ is eroded due to high rainfall in the location. High rainfall in these sites can result in strongly leaching. A previous research (Fatai, Shamshuddin, Fauziah, Radziah, & Bohluli, 2017) also state a high rainfall intensity occurs in palm oil plantation in Malaysia. Under a strongly leaching environment prevailing in the soil, much of the basic cation were lost to underground water during rainy seasons.

Fig. 4a shows the chemical properties in each topography influencing each other that P₂ is closely related to P₃ and P₄ is closely related to P₅, whereas P₁ is not related to others. It can be assumed that soil nutrient P₁ undergoes a leaching process to a lower topography P₂-P₅ so that P₂, P₃, P₄, and P₅ are related to each other. The slope of the Ayer Hitam Forest Reserve can also contribute to the transfer of soil material and soil properties. Tsui, Chen, & Hsieh (2004) state that steeper slope can contribute greater runoff and soil movement. Erosion on the topography is also influenced by vegetation on it. Ayer Hitam Forest Reserve has vegetation in the form of dipterocarp forests. It can be seen that P₁ has less dense trees and does not have shrubs, so that erosion is possible. Generally, erosion can be avoided if there are shrubs and dense tree canopies. Naharuddin (2017) states that tree canopies can protect direct sunlight exposure to the ground and can reduce rainwater splashing. Masnang, Sinukaban, Sudarsono, & Gintings (2014) also states that vegetation can protect the soil against rainwater that can destroy soil aggregates.

Several studies from Liu et al. (2018), Vásquez-Méndez et al. (2010), and Wei, Wu, Yan, & Zhou (2014) have stated that shrubs are most effective in reducing run-off and sediment levels, followed by herbaceous plants and trees. Vegetation also influences soil chemical properties, one of which is the high organic matter which can cause soil acidity at this location. Based on the results above, Fig. 4b shows the results of organic matter produced from the vegetation of each plot. The circles intersect with each other explain that they have a close relationship.

Fig. 4. Analysis of CVA about a) soil chemical properties with different topography, and b) Relationship organic matter with forest vegetation in Ayer Hitam Forest Reserve
The results of the chemical analysis found that organic matter in P1 to P5 at the first horizon is higher than the lower horizon. The organic matters containment in plots P1 and P5 was due to the accumulation of littering decomposition that undergoes the process of humification. The organic matter causes acidity at the surface of the soil. These conditions resulted in low pH on each layer surface P1 to P5, since the decreasing pH of each surface is also influenced by the high organic matter in the form of surface litter. The situation induced not only the soil acidity, but value of other nutrients as well. This is in line with the study of Tange, Yagi, Sasaki, Niyama, & Kassim (1998) that in the Semangkok Forest Reserve, Malaysia the nutrient content and soil acidity were highly correlated with the amount of organic matter on the surface of the soil. Zaidey et al. (2010) also found that the total value of carbon, nitrogen, available P, aluminum saturation, CEC was found to be high on the surface of forest soils in the Bidor and Kinta forests, Perak. The high chemical properties on the soil surface was also caused by a large amount of organic. Litter on the surface of the ground can maintain soil temperature, so that soil degradation is low. Soil physio-chemical can regulate high rainfall and temperature. Thus, the clay content in horizon B is quite high and can hold water capacity in the soil. According to Jusop & Ishak (2010), Ultisol soil in the subsoil has high clay content and can hold water capacity in the soil. Soil development and forest vegetation are complex and sustainable processes. Soil plays an important role in the development of forests, and forests also play an important role in the development of soil (Fisher & Binkley, 2000).

CONCLUSION

Research at the Ayer Hitam Forest Reserve now requires more adequate information about soil for better land and forest management. The high value of organic matter at the study site was due to the dense forest vegetation that was still undisturbed. High organic matter can cause a low pH value so that the soil becomes acidity on the surface, the role of parent material, and the environment also contributes to the acidity of the soil at this location. The soils at the research site are highly weathered and low fertility status so that it is categorized into the Ultisol order. Trees in the Ayer Hitam Forest Reserve are not only dominated by dipterocarp species but many species between Euphorbiaceae, Myrtaceae, Dipterocarpaceae, Malvaceae, Moraceae, Verbenaceae, Phylanthaceae, Santalaceae. Trees on the slope can protect from ground runoff to a lower place. Soil characteristics such as morphology, physicochemical, charge characteristics, and mineral composition need to be studied more deeply as a basis for soil management in the Ayer Hitam Forest Reserve.

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