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PHYSICO-CHEMICAL CHARACTERISTICS OF SOIL AT SUNGAI UDANG FOREST RESERVE, MALACCA, PENINSULAR MALAYSIA

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Abstract

A study was done to describe the soil characteristics and to determine the relationship between the soil properties of the forest reserve. A total of 25 plots were constructed and soil samples were collected from each plot of the study sites. A total of 1668 individual trees with diameter at breast height (DBH) of 5 cm and above were found in the 25 plots in Sungai Udang Forest Reserve, Malacca, Peninsular Malaysia. The overall floristic composition of the forest consists of 85 species belonging to 79 genera and 38 families. The soil in the studied area was acidic and dominated by clay loam which shows that the soil is suitable for the provision of nutrients to the plants. The correlation analysis between the physico-chemical characteristics of soil at all plots concluded that the correlation between the chemical content of soil in the area ranged from very weak to moderate. This is due to the fact that the strength of the correlation in this study for the absolute value of (r) ranged from as low as 0.007 (very weak) to 0.482 (moderate).

Key words: Pearson's correlation analysis, Peninsular Malaysia, Physico-chemical characteristics, Tropical Rainforest.

Introduction

A study on the heterogeneity of soil morphology and hydrology at the 50 ha long-term ecological research plot at Pasoh Forest Reserve, Peninsular Malaysia, showed that soil nutrient insufficiencies and imbalances are the most extensive edaphic constraint on tropical forests due to the generally high rainfall and intensive leaching in the forest (Adzmi *et al.,* 2010). The physico-chemical properties of disturbed soils in South Korea showed that the disturbed and accumulated soils display a great diversity in their physico-chemical properties in area around the globe (Ibrahim *et al.,* 2012). Plant available phosphorus, potassium, calcium and magnesium levels are the variables that most frequently found from the assessments of soil fertility in agricultural systems and forest ecosystems (Nykvist & Sim, 2009).

The accumulation and subsequent slow decomposition of organic matter which releases acids can be due to the reduction in pH (Haan, 1977). Some of the significant scopes in determining the site quality are the nature of soil profile, soil pH and nutrient cycle between soil and trees (Sharma & Kumar, 1991). In order for nutrient supply to be balanced, forest soils should be slightly acidic (Leskiw, 1998). According to Son *et al.* (2003), environmental and land-management factors influence the carbon storage and soils are the major reservoir of terrestrial carbon.

The main objective of this study was to describe the soil characteristics and to determine the relationship between the soil properties of the tropical forest reserve. One of the reasons why tropical rainforest was chosen in this study is because of its well-known complex terrestrial ecosystem. The tropical rainforest of Malaysia is very rich with flora and fauna biodiversity. Thus, it has a high amount of carbon stored and could act as a carbon sink which could ultimately contribute in mitigating climate change. However, the disturbing destruction due to human impact faced by the tropical rainforest in Malaysia and worldwide could cause the depletion of the tropical rainforest in the near future. This has led to an abundant of research on the tropical rainforest including the present study. It is highly expected that this study could increase the understanding of the tropical rainforest, thus, could be an advantage to the tropical forest management.

Materials and Methods

Study area: Data of the tropical trees were obtained from a 135 acre of forest reserve at Sungai Udang, Malacca, Malaysia (2°19′N, 102°8'E). The Sungai Udang Forest Reserve is a lowland forest which has a rough topography and ranges in altitude from 10 m to 90 m. The data were collected within the boundary of 20 hectares of forest reserve known as Compartment 4 which is an untouched preserve forest and are protected from the logging activities. The area has a tropical rainforest climate which is punctuated by much rainfall. The rainy seasons or heavy monsoon season occurs from October through March every year. The dry season occurs from May through July every year. The weather is warm and humid all year round with temperatures ranging from 21ºC to 32ºC. Mean annual rainfall of the study area is recorded as 2000 mm and it is considered to be one of the driest areas in Malaysia. Mean annual maximum and minimum precipitation is recorded as 74% and 35% respectively. The relative humidity typically ranges from 54% to 96% throughout the year.

Soil sampling: A total of 25 plots (20 m × 40 m) in size were constructed according to the line transect method. The size of the plots was estimated by means of a "minimal area" which was 800 m^2 in each plot. Plots were 20 m from each other. The plots were located at various altitudes, expositions, inclinations, and relief. Soil samples were collected from each 25 plots of the study sites. The litter from the surface was removed and soil was dug out using auger from the upper surface layers (0-30 cm) of the profile of the vegetation type. About 500 g of each sample from each plot was placed in polyethylene

bags and sample was mixed well individually. Then samples were air dried at 20 to 25°C, crushed and then passed through a 2 mm mesh sieve to remove the stone pieces and large root particles. The composite soil samples were used for detail analysis of different physiochemical characteristics in the soil laboratory.

Soil analysis: As for the physico-chemical analysis of soil, the following measurements such as pH (saturation slush, pH meter), electrical conductivity (saturation slush, electrical conductivity meter), carbonate (calcimeter), organic matter, and P were taken and determined by standard methods. Exchangeable cations (Na, K, Ca, and Mg) analyses were also done in the soil laboratory.

Statistical Analysis: Pearson Correlation Analysis was used to determine the correlation among the soil parameters. The formula for the correlation (r) was as follows;

$$r = \frac{1}{n-1}\left(\frac{\sum_x \sum_y (x-\bar{x})(y-\bar{y})}{s_x s_y}\right)$$

where, n = the number of pairs of data; $\bar{x}$ and $\bar{y}$ = the sample means of all the x-values and all the y-values, respectively; s_x and s_y = the sample standard deviations of all the x- and y-values, respectively.

The suggested strength of the correlation for the absolute value of (r) are; 0.00 to 0.19 as "very weak", 0.20 to 0.39 as "weak", 0.40 to 0.59 as "moderate", 0.60 to 0.79 as "strong" and 0.80 to 1.0 as "very strong".

Results

Physico-chemical analysis of soil: The results of the analysis of surface soil (0-30 cm) samples from 25 different plots were presented in Tables 1 and 2. Soil factors that were analyzed in this study included all the physical, chemical and biological properties of the soil. (Table 1) presents the physical characteristics of soil showing soil particle (%) and soil texture of the 25 sampling plots in Sungai Udang Forest Reserve, Malacca. Mean values of clay, silt and sand of the 25 plots were 50.72%, 24.32% and 24.96%, respectively. Thus, the analyses of particle size indicated that the soils of the studied area were dominated by clay loam texture whereby 4 out of the 25 plots showed this soil texture. (Table 2) shows the chemical properties of soil at all 25 plots in the study area. The soil pH varied from 4.11 to 4.95 (mean 4.65), clearly indicated that the soil had an acidic character. The mean range of the total cation exchange capacity (CEC) in this study was between 4.4 and 17.2 (mean 8.99), which was considered low. The available K in the study site was also low, ranging from 0.009 (c mol/kg) to 0.036 (c mol/kg) (mean 0.019). The available Mg in this study ranged from 0.144 (c mol/kg) to 0.601 (c mol/kg) (mean 0.304). The total C contents ranged from 1.46% to 2.99% (mean 2.07%). The total N contents varied from 0.09% to 0.69% (mean 0.28%).

Table 1. Physical characteristics of soil showing soil particle (%) and soil texture of the 25 sampling plots.

Plots	Clay %	Silt %	Sand %	Texture
1	44	16	40	Clay
2	20	44	36	Clay
3	60	36	4	Clay
4	40	44	16	Silty Clay
5	20	32	48	Sandy Loam
6	52	24	24	Clay Loam
7	20	20	60	Sandy Loam
8	64	28	8	Clay
9	68	28	4	Clay
10	64	20	16	Clay
11	24	8	68	Sandy Loam
12	32	20	48	Sandy Loam
13	56	12	32	Clay
14	44	16	40	Clay
15	52	44	4	Silty Clay
16	72	20	8	Clay
17	68	28	4	Clay
18	72	12	16	Clay
19	36	24	40	Clay Loam
20	60	28	12	Clay
21	64	32	4	Clay
22	64	24	12	Clay
23	60	8	32	Clay
24	56	20	24	Clay Loam
25	56	20	24	Clay Loam
Mean	50.72	24.32	24.96	Clay Loam
Min	20	8	4	Clay
Max	72	44	68	Clay Loam

Table 2. Chemical properties of soil of the 25 sampling plots.

Plots	pH	(c mol/kg)		CEC	C (%)	N (%)
		K	Mg			
1	4.56	0.024	0.362	9.8	2.99	0.45
2	4.76	0.015	0.183	8.9	1.46	0.34
3	4.44	0.018	0.350	5.8	1.62	0.32
4	4.82	0.015	0.330	8.6	1.76	0.22
5	4.68	0.013	0.293	8	2.35	0.27
6	4.5	0.021	0.229	8.3	1.54	0.23
7	4.52	0.020	0.601	10.2	2.51	0.27
8	4.59	0.014	0.410	10.6	4.21	0.29
9	4.73	0.020	0.251	7.7	1.64	0.21
10	4.11	0.018	0.315	7.5	2.19	0.20
11	4.7	0.017	0.208	6.9	1.76	0.17
12	4.74	0.031	0.230	5.4	1.81	0.17
13	4.7	0.036	0.431	7.4	1.69	0.16
14	4.82	0.023	0.265	8.3	2.04	0.16
15	4.53	0.011	0.385	8.7	1.61	0.15
16	4.67	0.013	0.298	8.6	1.81	0.48
17	4.82	0.019	0.313	8.5	1.84	0.41
18	4.88	0.016	0.372	10.5	2.26	0.43
19	4.48	0.016	0.244	14	2.86	0.17
20	4.94	0.012	0.297	4.4	1.50	0.13
21	4.95	0.021	0.500	17.2	2.38	0.11
22	4.87	0.009	0.144	15.4	1.55	0.09
23	4.58	0.023	0.185	6.3	1.53	0.36
24	4.4	0.029	0.230	10.8	2.63	0.69
25	4.52	0.022	0.171	7	2.24	0.47
Mean	4.65	0.02	0.30	9.0	2.07	0.28
Min	4.11	0.01	0.14	4.4	1.46	0.09
Max	4.95	0.04	0.60	17.2	2.99	0.69

Table 3. The correlation matrix of soil physico-chemical properties at Sungai Udang Forest Reserve.

	pH	Mg	K	P	CEC	C	N	%Clay	%Silt
Mg	0.007*								
K	- 0.150	0.079							
P	- 0.102	0.188	- 0.019						
CEC	0.172 *	0.219*	- 0.192	0.108*					
C	- 0.259	0.367***	0.014	0.482***	0.391**				
N	- 0.290	- 0.119	0.206*	- 0.085	- 0.098	0.256*			
%Clay	0.043	0.019	- 0.057	- 0.375	0.107	- 0.016	0.177		
%Silt	0.110	0.107	- 0.471	0.190	0.108	- 0.122	- 0.181	- 0.124	
%Sand	- 0.100	- 0.076	0.312**	0.234	- 0.156	0.082	- 0.060	- 0.837	- 0.440

*p<0.05; **p<0.01, ***p<0.001

Correlation analysis between soil properties: The correlation between the physico-chemical characteristics of soil at all the 25 plots in the Sungai Udang Forest Reserve was examined using the Pearson Correlation Analysis and shown in (Table 3). The clay was negatively correlated with silt where r = -0.124. Furthermore, clay also showed a highly negative correlation with sand where r = -0.837. The result indicated that soil with a high percentage of clay would have a lower percentage of silt and sand. In addition, silt was also negatively correlated with the percentage of sand where r = -0.440. There were also significant correlations between sand and available K (r = 0.312, p<0.01), but negative correlation between clay and P (r = -0.375), silt and K (r = -0.471).

Available P was significantly correlated to available C (r = 0.482 p<0.001). Available P also showed a positive correlations with CEC (r = 0.108, p<0.05). However, available P was negatively correlated to available K and available N with r = -0.019 and r = -0.085, respectively. CEC was significantly correlated with available C (r = 0.391, p<0.01). CEC also showed a positive correlations with Mg (r = 0.219, p<0.05) and P (r = 0.108, p<0.05). However, CEC showed a negative correlation with available K and available N with r = -0.192 and r = -0.098, respectively. Available C also showed a significant correlation with Mg (r = 0.367, p<0.001) and N (r = 0.256 p<0.05). Available N also had a positive correlation with K (r = 0.206, p<0.05).

The pH in this study was positively correlated with both available CEC (r = 0.172, $p<0.05$) and Mg (r = 0.007, $p<0.05$). Meanwhile, the pH in this study was negatively correlated with available K (r = -0.150), available P (r = -0.102), available C (r =-0.259) and available N (r = -0.290).

Discussions

Relationship between soil physico-chemical properties: The correlation analysis between the physical properties of soil at all the 25 plots in the Sungai Udang Forest Reserve concluded that the clay was negatively correlated with silt. The clay also showed a highly negative correlation with sand, which indicated that soil with a high percentage of clay will have a lower percentage of silt and sand. Furthermore, the studied physical characteristics of soil showing soil particle and soil texture of the 25 sampling plots showed the soils of the study area were dominated by clay loam texture. Clay loam is classified as a loam in which clay is dominant (Khairil *et al.*, 2014). The structure of loam which is not too compact, allowing roots to penetrate while water and air in the soil are balanced, thus, make the texture of loam more suitable for plantation activities (Othman & Shamshuddin, 1982). The water content, soil fertility, soil erosion, soil temperature and water holding capacity are greatly affected by the physical properties of soil (Sarangzai *et al.*, 2015).

According to Martins *et al.* (2015), the growth of tropical trees is strongly affected by soil texture, nutrient concentration and moisture levels in different ways. Soils with medium clay content (30-60%) have a tendency to favor tree height and diameter growth. Hence, it is estimated that the dynamics of tropical forests are influenced by variations in soil characteristics.

The correlation analysis between the chemical properties of soil showed that the pH value was positively correlated with both available CEC and available Mg but the correlations were low. This indicated that highly acidic soil will have a higher content of CEC and available Mg. Meanwhile, the pH in this study was negatively correlated with available K, available P, available C and available N. It showed that highly acidic soil will have a lower content of available K, available P, carbon and nitrogen. The pH values in the study area varied between 4.11 and 4.95 obviously showed that the soil was acidic in nature and there was no major difference in the pH values of the soil samples in all stands at different plots. Soil pH has a direct effect on the availability of most of the nutrients and is significant for proper nutrient management (Ahmad *et al*., 2011). The pH determines the acidity or alkalinity of soil and the chemical reaction between water and soil minerals is also affected by the pH of soil (Arain *et al.*, 2000). High organic matter content and the undisturbed nature of the soils in the study area contributed to the low pH of the soil (Gairola *et al.*, 2012). A study by Khairil *et al.* (2014) reported a similar result with this study, of which all soil found in the three forest types of the study area in Peninsular Malaysia which were inland forest, seasonal flood forest and riverine forest showed a low pH and acidic in nature.

According to Othman Shamshuddin (1982), most soil in Peninsular Malaysia tropical rainforests was acidic with pH values between 3.5 and 5.5. It is common for soil to become so weathered and leached in wet tropical regions which caused high acidity in the soil. According to Khairil *et al.* (2014) the total sum of exchangeable cation that can be adsorbed by the soil is known as cation exchange capacity (CEC). The role of CEC was to measure the fertility, the capacity of nutrient retention and the capacity to protect groundwater from cation contamination. The content of clay and organic matter influence the cation exchange capacity. In this study, the content of clay was positively correlated with cation exchange capacity indicating that soil with a high content of clay would have a higher cation exchange capacity. The cation exchange capacity will become higher if the percentage of clay and organic matter is higher (Othman & Shamshuddin, 1982).

Furthermore, according to the Pearson correlation analysis, the CEC in this study was significantly correlated with available C. This indicated that soil with a high CEC will have a higher available carbon. CEC also showed positive correlations with available Mg and available P but both correlations were low. However, CEC showed a negative correlation with both available K and available N.

The mean range of the total cation exchange capacity (CEC) in this study was between 4.4 and 17.2 meq/100g. A study on the soil physico-chemical characteristics from three forest types in tropical watershed forest of Chini Lake, Peninsular Malaysia produced quite a similar result of CEC with the range of mean values of the cation exchange capacity in the inland forest was between 4.59 and 12.99 meq 100g, the seasonal flood forest was between 4.63 and 16.70 meq 100g, while the riverine forest indicated between 5.66 and 13.888 meq 100g (Khairil *et al.*, 2014).

This study also observed a positive correlation between nitrogen and K. This indicated that the soil in this study with a high content of nitrogen will also have a high content of available K. The values of total nitrogen in the study area ranged between 0.09% (Plot 22) and 0.69% (Plot 24). The value of total nitrogen in Plot 24 was the highest due to higher water holding capacity and the presence of heavy litter and humus content of the studied forest types. The amount and properties of organic matter largely influenced the availability of nitrogen (Haan, 1977). Therefore, the low amount of organic matter in the forest types of Plot 22 was also one of the reasons for the lowest value of nitrogen as compared to other plots.

Available C was significantly correlated to available P with r = 0.482. This indicated that the soil in this study with a high content of carbon will also have a high content of available P. Available C also showed a significant correlation with available Mg (r = 0.367) and N (r = 0.256). However, available P was negatively correlated to available K and available N in this study. This indicated that soil with a high content of available P will have a lower content of available K and available N.

Overall, the correlation analysis between physico-chemical content of the soil in the study area showed that the correlation ranged from very weak to moderate. This is due to the fact that the strength of the correlation in this study for the absolute value of (r) ranged from as low as 0.007 (very weak) to 0.482 (moderate).

Conclusions

The physico-chemical characteristic of the soil at Sungai Udang Forest Reserve was acidic and dominated by clay loam which shows that the soil is suitable for the provision of nutrients to the plants. Therefore, the soil characteristics of an environment are an important criterion for species distribution. The correlation analysis between chemical content of the soil in the study area concluded that the correlation ranged from very weak to moderate. This might be due to the anthropogenic disturbances, animal grazing or effect of flooding in the forest. Further research especially regarding the relationship of soil characteristics with forest vegetation is important to add more data to this preliminary research.

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