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Assessment of chemical properties of tropical peatland soil in Malaysia oil palm plantation

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Abstract

The chemical assessment of the peatland in oil palm plantation in South Selangor Peatland Swamp in Malaysia were evaluated in this study. Soil samples were obtained from fifteen (15) different locations within the study area at three different depths of 0.5m, 1.5 m, and 2.5 m in three replicates at each depth, using peat auger between March and July, 2013 during the secondary maximum rainfall. Parameters evaluated in soil analysis included - pH, moisture content, carbon, nitrogen, sulphur and heavy metals such as manganese, zinc, iron, copper, and phosphorus. Heavy metals were determined using the double acid extraction method while carbon, nitrogen, and sulphur was determined using Trumac CNS Analyzer. From the pH values, the soil close to the surface is more acidic with a mean pH of 3.36 and standard error of 0.15. The mean values of the moisture contents were 363.54 % with SEM of 27.01 and 154.56 % with SEM of 54.64 at 0.5 m and 2.5 m depths respectively. Carbon, had the highest value of 44.27 % at 0.5 m, nitrogen, 0.36 %, sulphur, 0.15 % and heavy metals like manganese, iron, and copper, except zinc, and phosphorus had their mean values either increasing or decreasing with soil depth. Soil carbon was observed to decrease with depth unlike nitrogen and soil pH. All the parameters were observed to either decrease or increase with depth which shows their spatial distribution across the soil mass. This assessment of the tropical peatland soils chemistry has helped in appraising the important roles played by intact peatlands in overall global environmental sustainability.

Keywords: Chemical Properties, Tropical Peatland, Oil Palms Cultivation, Soil Quality, Greenhouse Gases.
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Introduction

Peat soil accumulates naturally under anaerobic condition which favours the incomplete decomposition of organic matters to form peats (Sabiham *et. al.*, 2012). Szajdak *et. al.* (2007) described peat as representing a mixture of organic compounds characterized by high molecular weight. Driessen (1978) and Wosten and Ritzema (2001) also defined peat as soils that contain at least 65% organic material, and is at least 50 cm in depth and covers an area of at least 1 ha and is acidic. Surface peat covers (SPCs) which are thicker than 40cm and classified as different types of HS, according to Kolli *et. al* (2009), form superficial biological active layers within peatlands or overlying peat deposit. Peatland basins are found in many parts of the world, both in temperate and tropical regions (Ayob, 2005). Hugo (1980) indicates that out of 400 million hectares, or 11% of the world area of peatland resources in the world, about 72 million hectares alone are found in the tropic. From this estimate, 23 million hectares are in the Southeast Asia, and as reported by Mutalib *et. al.* (1992), about 24 million hectares (7% of the total land area) is located in Malaysia. Out of this, the three regions that make up Malaysia share the area as follows; 1 million ha. - Peninsula Malaysia, 1.6 million ha. - Sarawak, and about 0.8 million ha. - Sabah. According to Fitzherbert *et. al.*, (2008) and Meyer (1996), owing to the boom recorded in oil palm industry in these regions in the 1980s, many swamp forests in the regions have been converted to oil palm plantation through deforestation thereby exposing the soil to atmosphere. According to Wakker (2004), despite the recent global economic meltdown, the high demands for oil palms still remain the main factors behind the logging activities experienced in Southeastern part of the Asian region (Indonesia and Malaysia, especially), where above 50% of the oil palm expansion between years 1990 and 2005 has claimed the native forest (Koh and Wilcove, 2008). Armentano and Menges (1986) had noted that about 75% of wetlands by area are peatlands. In their study, Maltby and Immirzi (1993) noted that although peatlands occupy only 3% of the Earth's land area, they can store up to 525 Gt (1 Gt511015g) of carbon. Tropical peat covers between 0.3 and 0.5 M km^2 (Immirzi *et. al.*, 1992; Maltby, 1997). And based on the figure by Post *et al.*, (1982) and Rieley and Page (1997), the tropical peat carbon store is about 191–202 Gt. Lal (2004) reported that deforestation, excessive farming practices and fossil fuel combustion have been largely responsible increase in atmospheric concentration of CO_2 by 31 %. He further stressed that this anthropogenic enrichment of green house gases (GHGs) in the atmosphere has led to an increase in the average global surface temperature by 0.6°C. Therefore, efforts are being put in place to discourage logging and these excessive agricultural activities within the swamp forests so as to stop further exposure of these soil nutrients to the atmosphere and to excessive surface runoff where major nutrients in the soil are washed off as a result of high discharge rates (Anderson, 1970; Moscrip and Montgomery, 1997).

According to Butterbach-Bahl (2011), nitrogen that enters the soils is biologically and chemically transformed through soil mineralization and immobilization in soil organic matter. This author further revealed that input of excess of nitrogen to the soil, affects soil organic matter content, decreases soil biodiversity and decreases the filtering and buffering capacity of the soil. Uncontrolled application of fertilizers has been seen as increasing the contents of nitrates in the peat soil which in turn affects the quality of groundwater because of their acidifying effects (Harmsen *et. al.*, 1990). Nitrogen has been found to be lost from the soil in form of Nitrous oxide (N_2O) through the process known as nitrification and denitrification (Koops *et. al.*, 1991). He affirmed that N_2O produced from the peat is considered as nitrogen N loss because it is being exposed to the atmosphere as N_2O or N_2. Wang *et. al.*, (1976) stated that interest in N_2O production in soil is mostly based on its contribution to the enhanced greenhouse effect. Brown (1986) reported that chemical and biochemical transformation of sulphur compounds within the peat systems have a considerable influence on the behavior of other elements present in the peat soil. Sulphur is understood to be present in the soil predominantly as bound organic sulphur with small amount in quasi-equilibrium as sulphate (SO4-S). Sulphate, according to Blodau *et al.*, (2007), is important for rates and pathways of anaerobic carbon mineralization because its presence may reduce methane production through competition of anaerobic bacteria for substrate. Phosphorus in the other hand has been identified by Nieminen and Penttila (2004) as one of the key nutrients for satisfactory tree growth on drained peatland.

Therefore, this study, assesses the chemical composition of South Selangor peatland swamp forest with a view to investigate their variation with depth up to the mineral soil and to check their concentration levels and possibly proffer a solution to prevent further loss of these parameters to the atmosphere in a bid to reduce the menace of climate change.

Materials and methods

Study area

The study site is located at Kuala Langat South Forest Reserve area, sharing the same boundary with the Malaysian Kuala Lumpur International Airport (KLIA) between latitude 02° 43'N and longitude 101° 39'E (Fig. 1). As at 1927 when the area was first gazetted as a forest reserve, the size was 12.141ha. and this has since been reduced to half its original size due to different land use practices. The area is characterized with tropical climate and high humidity with an annual rainfall between 2500 – 3000mm during the year. Mean rainfall in November is 11 mm day^{-1} and this happens to be the highest in the year with a total annual rainfall depth of 1637.6 mm. The temperature ranges between 26.1°C and 27.2°C, with the highest value recorded in May. The correlation analysis using IBM SPSS Statistics 21 was employed in the study to check the correlation of the parameters and to check the statistical significance of the results.

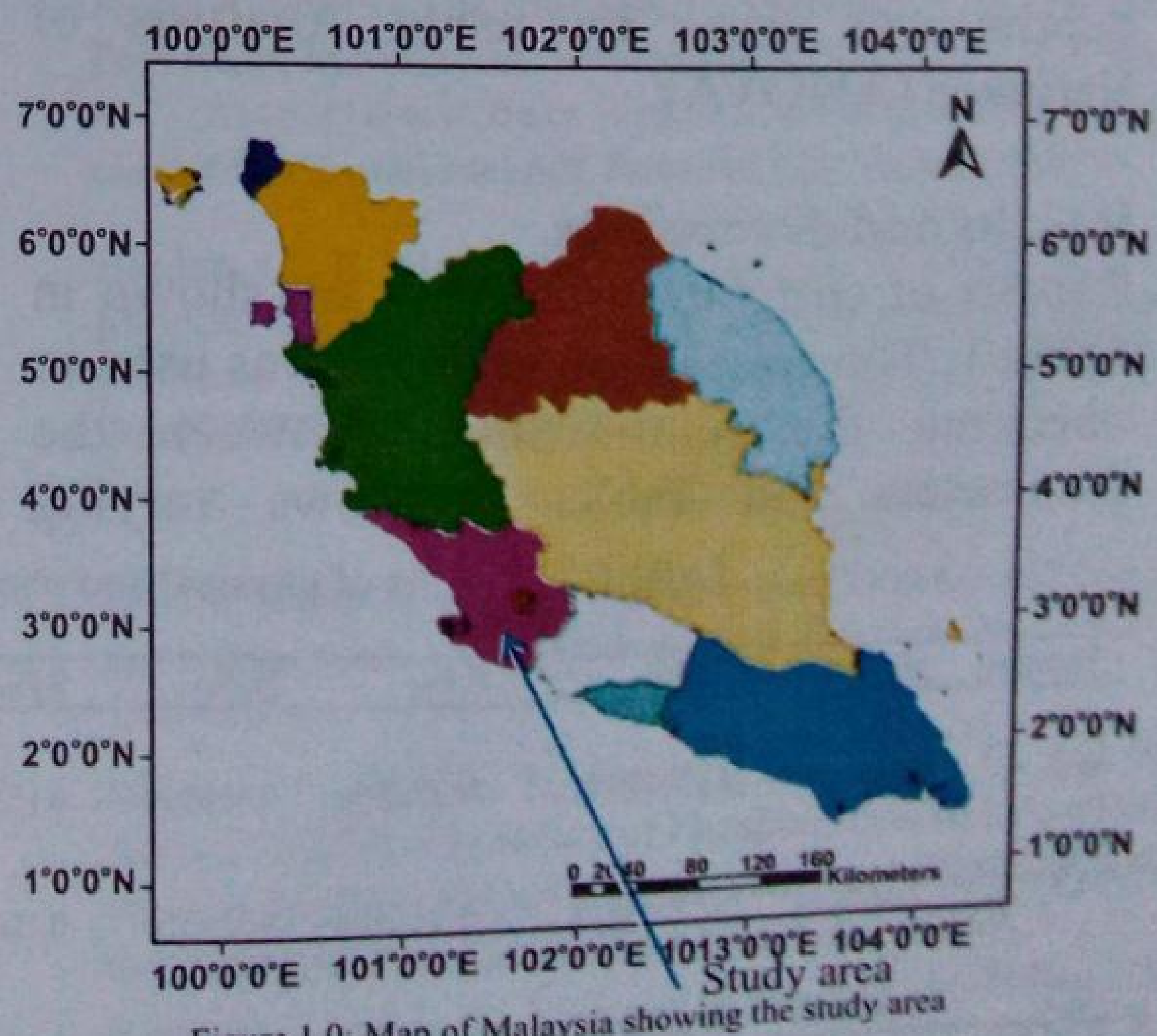

Figure 1.0: Map of Malaysia showing the study area

Soil sampling

Soil materials were obtained from fifteen (15) different locations within the study area at three different depths of 0.5 m, 1.5 m, and 2.5

m in three replicates at each depth, making the total of forty-five (45) samples in all. Peat auger was used in extracting the soil samples out at various depths from each of the 15 locations before the samples were then placed in well-labeled polythene bag. The soil samples were taken to laboratory where both physical and chemical analyses were conducted on them. Double acid method of extraction was used for iron, (Fe), zinc, (Zn), copper, (Cu), manganese, (Mn), phosphorus, (P) (Kathuli *et. al.*, 2007; Hagedom, 2008). A volume of 25 ml of prepared double acid was mixed with 5 g of soil samples that passed through 2 mm sieve and placed in a shaker for 15 minutes (Kathuli *et. al.*, 2007). The mixture was filtered and the filtrate analyzed for Fe, Zn, Cu, Mn, and P. Carbon, Nitrogen, and Sulphur (CNS) are analysed using *Trumac* CNS Analyzer. The results came out in triplicates and the mean with standard error of means at various depths are as shown in Table 1. The *pH* values of the samples were determined following the procedures of Adesiji *et. al.* (2014). This was also done in triplicates. The same went for soil moisture contents where the values were recorded in triplicates and the mean and standard errors of means shown in Table 1.

Statistical analysis of data was carried out using correlation analyses and Statistical Analysis System (SAS) version 9.2. Comparison of means for each of the parameters and means comparison between depths was done by using Analysis of Variance (ANOVA).

Results and discussions.

Results of correlation analysis are shown in Table 1. The correlation analysis was used in checking the relationships between the parameters and Tables 2 shows varying degrees of correlation among the parameters. *pH* has the correlation of 0.924 with soil depth which shows positive correlation with depth and -0.98 with soil moisture which means negative correlation. All the parameters analyzed showed negative correlation with depth except nitrogen, sulphur and *pH*. From the *pH* values, the soil is more acidic close to the surface with the pH ranging from from 3.36 ± 0.15 to 3.50 ± 0.13. In this study, pH of water showed no significant difference between depths (ANOVA, $p>0.05$).

Moisture content ranged from 154.56 ± 54.64 at 2.5 m to 362.54 ± 27.01 at 0.5 m, with no significant difference between depths (ANOVA, $p>0.05$). The reading for carbon ranged from 16.77 ± 2.55 at 2.5 m depth to 44.27 ± 2.53 at 0.5 m depth, also with no significant difference between depths (ANOVA, $p>0.05$). It reveals that the carbon content of the soil increases with depth (about 50 % of the soil organic matter). Furthermore, it shows that much of the soil carbon is stored deep in the soil and thus must be prevented from being exposed to the atmosphere as a result of land use practices to avoid nutrients' loss and consequent effects of climate change.

Values of nitrogen and sulphur ranged from 0.36 ± 0.13 and 0.15 ± 0.01 at 0.5 m to 0.62 ± 0.13 and 0.36 ± 0.09 at 2.5 m respectively. There were no significant differences in nitrogen and sulphur between depths tested (ANOVA, $p>0.05$). Increase in Nitrogen concentrations with depth has also been attributed to some farming practices, like fertilization and herbicide application and the movement of the compounds down the soil depth. Higher concentration of nitrogen at 2.5 m depth is attributed to movement of nitrogen compounds from applied fertilizers over the period of time.

TABLE 1: Results of physical and chemical analyses on soil samples (Mean ± SE)

Depth(m)	pH	MC (%)	C (%)	N (%)	S (%)	Mn (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	P (mg/kg)
0.5	3.36±0.15	362.54±27.01	44.27±2.53	0.36±0.13	0.15±0.01	6.62±1.92	8.04±3.11	331.06±101.20	4.84±2.82	7.78±1.62
1.5	3.48±0.13	137.93±48.76	31.93±4.08	0.52±0.05	0.11±0.04	3.35±0.09	7.26±2.05	226.51 ± 92.30	2.63±1.83	5.36±1.52
2.5	3.50±0.13	154.56±54.64	16.77±2.55	0.62±0.13	0.36±0.09	5.52±1.02	7.88±0.99	145.22 ± 75.99	0.90±0.28	6.32±1.43

	Depth (m)	pH	MC (%)	C (%)	N (%)	S (%)	Mn(mg/Kg)	Zn(mg/kg)	Fe(mg/kg)	Cu(mg/kg)	P (mg/Kg)
Depth (m)	1.000										
pH	0.924**	1.000									
MC (%)	-0.831**	-0.980**	1.000								
C (%)	-0.998**	-0.900**	0.797**	1.000							
N (%)	0.991**	0.967**	-0.897**	-0.982**	1.000						
S (%)	0.782**	0.485	-0.303	-0.817**	0.693**	1.000					
Mn (mg/Kg)	-0.331	-0.665**	0.800**	0.274	-0.452	0.330	1.000				
Zn (mg/Kg)	-0.194	-0.554*	0.707**	0.136	-0.322	0.460	0.990**	1.000			
Fe (mg/Kg)	-0.997**	-0.950**	0.869**	0.991	-0.998**	-0.735**	0.398	0.264	1.000		
Cu (mg/Kg)	-0.998	-0.949**	0.868**	0.992**	-0.998	-0.736**	0.396	0.263	1.000	1.000	
P (mg/Kg)	-0.599*	-0.859**	0.943**	0.551*	-0.700**	0.031	0.954**	0.902**	0.655**	0.654**	1.000

** Correlation is significant at $P = 0.01$ level, * Correlation is significant at $P = 0.05$ level.

All the heavy metals tested gave no significant differences between the depths tested (ANOVA, $p>0.05$) except phosphorus (ANOVA, $p<0.05$). Iron gave the highest values ranging from 145.22 ± 75.99 at 2.5 m depth to 331.06 ± 101.20 at 0.5 m depth, followed by phosphorus ranging from 6.32 ± 1.43 at 2.5 m depth to 7.78 ± 1.62 at 0.5 m depth. Among all the heavy metals tested, copper gave the lowest value that ranged from 0.90 ± 0.28 at 2.5 m depth to 4.84 ± 2.82 at 0.5 m depth. The availability of phosphorus at 0.5 m in appreciable quantity justifies the types of fertilizers being used (NPK) and fertilization of the soil during the farming period which then reduces in quantity with depth

High level of carbon at near soil surface NSS, has also confirmed the soil to be peaty, and decrease in the carbon values with depth up to 2.5 m shows that the peat is a deep one. Higher concentration of phosphorus at 0.5 m depth is attributed to the type of fertilizers in use, which is ammonium phosphate. The decrease in values of the heavy metals from 0.5 m to 2.5 m is as a result of soil's high level of acidity within the soil mass. The higher concentration of iron (Fe) is attributed to microbial activity between the soil and groundwater and this is interpreted as a change in the capacity of organic matter to bind the metal (Tarutis *et. al.*, 1992).

Conclusion

The study has shown that the physical-chemical parameters of peat soil in the Malaysian tropical peatlands vary in their concentrations with respect to depth. And in conclusion, therefore, land use and other management policies like deforestation, fossil fuel burning and fertilizations have been observed to have contributed in various ways to the parameters' levels of concentration. Hence, assessing the chemistry of tropical peatland soils has helped in appraising the important roles played by intact peatlands in overall global environmental sustainability.

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