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Impacts of Oil Palm cultivation on Soil chemistry in a Malaysian Tropical Peatland

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ABSTRACT

Cultivation of oil palm on peat soil has greatly affected the environment and soil carbon in recent time, especially when such practice has been on for several years. This paper therefore considers the impacts of oil palm cultivation on the peat soilwith depth and considering the heterogeneity of different ages of plantation. Soil analyses were carried out and the parameters considered in soil analyses are; pH, moisture content, carbon, nitrogen, sulphur, and some heavy metals like, manganese, zinc, iron, copper, and phosphorus. Heavy metals present in the soil were determined using the double acid method while carbon, nitrogen, and sulphur were determined using flash combustion method. The results of the soil analysis indicated strong correlations among carbon, nitrogen, sulphur, depth and pH. Carbon values ranged from the highest (50.08%) in the oil palm cultivated in the year 2000 to the lowest (33.20%) in 2010-cultivated oil palm at the same depth, which suggests that carbon content of peat soil might be decreasing with continuous oil palm cultivation.Hence the gradual loss of carbon content from the peatland with time is being attributed to the oil palm cultivation and this could also trigger climate change effects, if left uncontrolled. The same applies to other parameters analyzed but with either negative or positive correlation observed.

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INTRODUCTION

Peatland in Malaysia are primarily coastally formed, developing behind mangroves where sulphides in the mud and water as well as anoxia restrict bacterial activities, leading to reduced decomposition of plant debris and accumulation of organic matter as peat [1]. [2] and [3] defined peat soil as a soil that contains at least 65% organic material, is at least 50 cm in depth, covers an area of at least 1 ha and is acidic. Peat soils occupy about 2.7 million hectares in Malaysia of which about 1.7 million hectares occur in Sarawak and about 0.7 million hectares in Peninsular Malaysia and about 0.3 million hectares in Sabah. This represents about 10% of total peat soils found in Southeast Asia [4]

Malaysia is one of largest producers of palm oil globally. This rapidly expanding industry has resulted in *circa* 5.3 million ha of oil palm (OP) plantation land surface cover [5]. Globally, oil palms plantation is greatly aiding the conversion of the forest lands into oil palm plantations for the sole purpose of meeting up with increasing global demands for oil palms. The use of palm oil for bio-fuels has also been attributed to the driving force behind the expansion of the global oil palm production; mainly because of supportive measures of several governmental authorities. According to [1], there are approximately 25 million ha of peat land in oil palm growing countries. However, the homogeneity of soil features, constant availability of soil water, and flatness are what make peat soils suitable for oil palm growth. In Malaysia alone, of all the 14 million ha of agricultural land available, 19.5 million ha (59 %) are forested land as at 2008, where the total cultivated land is 6.6 million ha (20 %), of which 5.3 million ha (14 %) of the land being used for oil palm cultivation [5]. With the values highlighted above, it is very clear that oil palms occupy a larger percentage of the total cultivated land in the whole Malaysia when compared with other agricultural cultivations.

Despite the disruptive land use practices used in preparation for oil palm cultivation on peat soils (e.g. deforestation, bush burning, drainage and fertilization [6], there have been few studies which addressed the potential negative ecological consequences associated with OP conversion in peat soils. Those which have been undertaken have recorded altered physical and chemical properties of the soil and groundwater quality within

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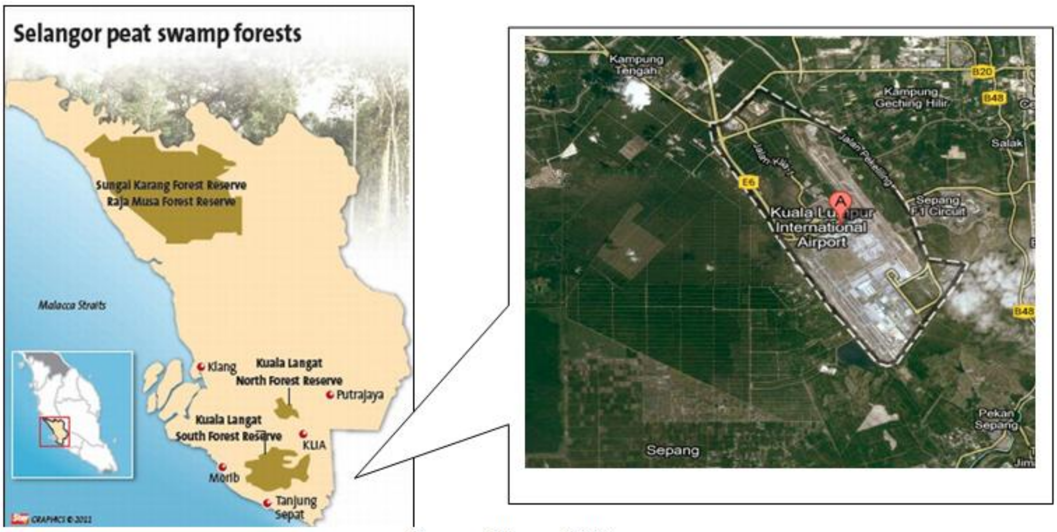
the peatland [7]. According to [8], the insecticides, herbicides, and fertilizers used as means of boosting oil palm produce may enter water bodies as runoff or groundwater seepage and can seriously impact aquatic biodiversity. About a third of peat land areas in the coastal lowland of Sarawak have been converted to oil palm plantation and this has caused the destruction of biodiversity, loss of soil carbon and serious threat to the water resources in the peat swamp forests area [9].

Also, conclusions from various works have it that due to the agricultural practices, most of the carbons stored within the peatlands have been lost to the atmosphere [10], and natural hydrologic conditions altered within a watershed [11]. [12] also noted that agricultural and urban land use often increases stream inorganic Nitrogen (N) and Phosphorus (P) calculation, but less is known about the impacts of human land use on the cycling of organic carbon and Nitrogen within the peatland, both in the soil and in the groundwater quality. Hence, this study focuses on the impacts of oil palm cultivation as a form of land use activities on the physical and chemical parameters of the peat soil. This becomes necessary so as to appraise the impacts of the various forms of uses the land is subjected to most especially swamp forest converted to oil palm plantations.

MATERIALS AND METHODS

Study area:

The study area is located at Kuala Langat South Forest Reserve, within the perimeter of Kuala Lumpur International Airport (KLIA), Malaysia at latitude 02^{o} 43'N and longitude 101^{o} 39'E (Fig. 1). The area experience tropical climate and high humidity with an annual fainfall between 2500 – 3000 mm during the year. The mean rainfall in November is 11 mm day^{-1} which happens to the highest in the year. The temperature ranges between 26.1^{o}C and 27.2^{o}C, with the highest value recorded in May every year.



(*Source: Cheng, 2011*)

Fig. 1: Location of the study area.

Data collection:
Soil sampling:

The entire study area was divided into four plots of different years of cultivation of oil palm plantations: 2000, 2002, 2006, and 2010. Each plot was further divided into two sections each with an augered hole where the soil samples were collected at three different depths; 0.5 m, 1.5 m and 2.5 m. As these holes were been dug, the soil samples were also being taken at different depths for the purpose of soil analysis. 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 parameters such as iron, (Fe), zinc, (Zn), copper, (Cu), manganese, (Mn), phosphorus, (P). 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. The mixture was filtered and the filtrate analyzed for Fe, Zn, Cu, Mn, and P.Carbon, Nitrogen, and Sulphur are determined using flash combustion methods which does not involve the use of chemicals as opposed to Kjeldahl method where acids are being used as metals extracts. Air-dried, 2 g of soil samples that passed through 2mm sieve were placed in the plastic containers, well covered and then transferred to the Flash combustion, Carbon, Nitrogen, and Sulphur analyzer. The results came out in triplicates and the average results are as shown in Table 1. The pH of the samples were determined on a 1:1 (v/v) soil-water mixture. 20 ml of distilled water was added to 5 g of oven-dried soil samples that passed through 2 mm sieve. The mixture was stirred intermittently with glass rod for the period of 30 minutes. The *pH* was then measured on a Beckman pH meter and the reading recorded.

RESULTS AND DISCUSSIONS

Soil analysis:

Summary of the results of the analysis conducted on soil samples is as shown in TABLE 1 below. The TABLE presented the parameters' values recorded at different depth per each 'Age of plantation'. The correlation analysis was used in checking the relationships among the parameters and TABLES 2 (a-d) show the correlation coefficients for the different ages of planting from; 2000-2010.

Table 1: Results of Physical and Chemical properties of soil samples with mean and standard error of means

YEAR	DEPTH (m)	pH	Mois. Content.%	Carbon %	Nitrogen %	Zn (mg/kg)	Cu (mg/kg)	Fe (mg/kg)
2000	0.5	3.71 ±0.03	395.10±61.72	50.08 ± 4.26	1.31 ± 0.15	4.12 ± 0.33	64.0 ± 62.58	54.46 ± 14.84
	1.5	3.73 ± 0.02	348.98±138.06	45.57 ± 0.23	1.20 ± 0.12	5.85 ± 0.71	15.45 ± 11.16	56.99 ± 1.90
	2.5	3.72 ±0.02	459.09±143.45	47.34 ± 0.06	1.92 ± 0.02	7.70 ± 1.77	1.75 ± 1.58	69.63 ± 21.39
2002	0.5	3.14 ± 0.01	361.12 ± 0.35	44.84 ± 0.27	1.36 ± 0.01	17.40±12.59	0.95 ± 0.38	562.63 ±19.27
	1.5	3.16 ±0.01	283.08±122.25	26.04 ± 0.23	0.61 ± 0.01	7.28 ± 4.17	0.81 ± 0.28	177.73 ± 78.49
	2.5	3.24 ± 0.01	380.83 ± 15.24	43.41 ± 0.21	1.17 ± 0.03	5.87 ± 0.94	0.55 ± 0.07	56.65 ± 4.10
2006	0.5	3.15 ± 0.02	382.46 ± 21.78	34.96 ± 0.62	0.95 ± 0.02	3.24 ± 0.01	0.78 ± 0.01	29.57 ± 0.11
	1.5	3.21 ± 0.01	364.88 ± 17.65	20.27 ± 0.03	0.36 ± 0.01	4.63 ± 0.08	0.67 ± 0.02	55.04 ± 6.52
	2.5	3.30 ± 0.01	197.29 ± 7.50	25.47 ± 0.04	0.49 ± 0.01	7.20 ± 0.02	0.51 ± 0.02	128.50 ± 4.03
2010	0.5	3.44 ± 0.01	233.73 ± 13.79	33.20 ± 0.03	1.21±0.002	5.00 ± 0.62	0.62 ± 0.04	526.88±39.78
	1.5	3.57 ± 0.04	146.47 ± 7.96	24.12 ± 0.06	0.62 ± 0.10	8.34 ± 0.16	0.61 ± 0.01	391.28±256.04
	2.5	3.69 ± 0.02	126.77 ± 3.87	11.86 ± 0.15	0.26±0.002	11.99 ± 0.04	0.61 ± 0.01	325.13±382.72

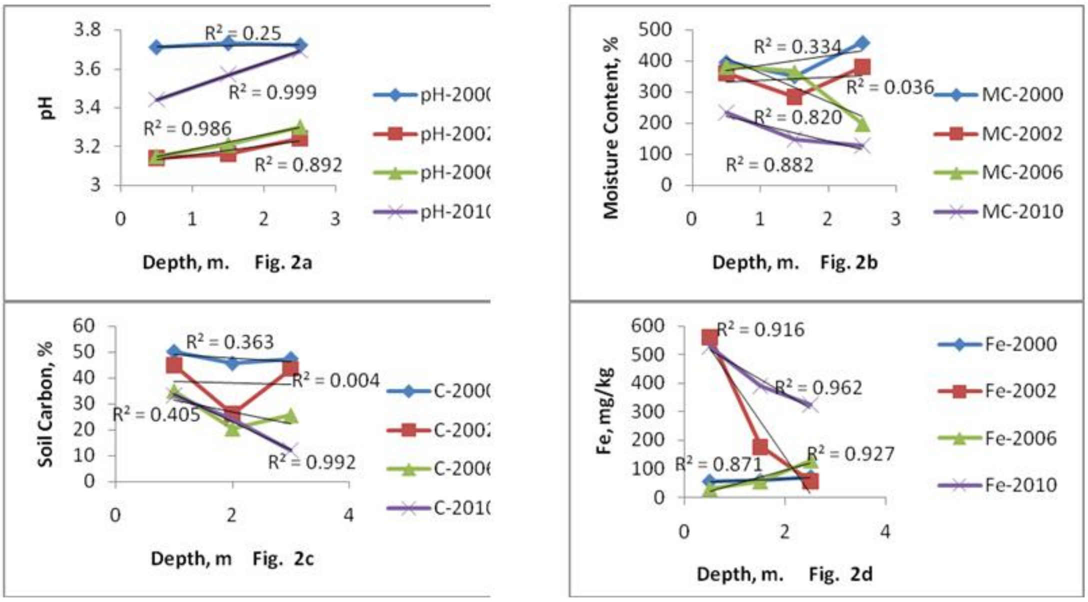


Fig. 2: Correlations of physical and chemical properties with soil depth. 2a shows the pH values correlation with depth. 2b shows Moisture content correlation with depth. 2c shows correlation of Soil carbon with depth. 2d shows correlation of Iron, Fe with depth

Table 2a: Correlation coefficients of Physiochemical Variables for 2000-Year of plantation.

	Depth	*pH*	*MC*	*C*	*N*	*S*	*Mn*	*Zn*	*Fe*	*Cu*	*P*
Depth	1.00										
pH	-0.65**	1.00									
MC	-0.73**	-0.04	1.00								
C	-0.87**	0.19	0.97**	1.00							
N	-0.86**	0.19	0.97**	1.00	1.00						
S	-0.98**	0.50*	0.85**	0.94**	0.94**	1.00					
Mn	-0.90**	0.92**	0.35	0.56*	0.56*	0.80	1.00				
Zn	-0.49**	0.98**	-0.24	-0.02	-0.02	0.31	0.82**	1.00			
Fe	-0.52*	0.99**	-0.21	0.02	0.02	0.35	0.84**	1.00	1.00		
Cu	-0.88**	0.22	0.97**	1.00	1.00	0.95**	0.58	0.01	0.05	1.00	
P	-0.92**	0.30	0.94**	0.99**	0.99**	0.98**	0.65**	0.10	0.14	1.00	1.00

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Table 2b: Correlation coefficients of Physiochemical Variables for 2002-Year of plantation

	Depth	*pH*	*MC*	*C*	*N*	*S*	*Mn*	*Zn*	*Fe*	*Cu*	*P*
Depth	1.00										
pH	0.94**	1.00									
MC	-0.77**	-0.52*	1.00								
C	-0.07	-0.39	-0.58*	1.00							
N	-0.24	-0.55*	-0.43	0.98**	1.00						
S	0.16	-0.18	-0.75**	0.97**	0.92**	1.00					
Mn	-0.92**	-1.00	0.46	0.45	0.60	0.24	1.00				
Zn	-0.99**	-0.98**	0.69**	0.18	0.35	-0.04	0.96**	1.00			
Fe	-0.87**	-0.98	0.35	0.55*	0.69	0.35	0.99**	0.92**	1.00		
Cu	0.85**	0.63**	-0.99**	0.47	0.30	0.65**	-0.58*	-0.79**	-0.48	1.00	
P	-0.97**	-1.00	0.60**	0.30	0.47	0.08	0.99	0.99	0.96	-0.70**	1.00

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Table 2c: Correlation coefficients of Physiochemical Variables for 2006-Year of plantation

	Depth	*pH*	*MC*	*C*	*N*	*S*	*Mn*	*Zn*	*Fe*	*Cu*	*P*
Depth	1.00										
pH	0.93**	1.00									
MC	-0.94**	-0.75**	1.00								
C	0.16	-0.22	-0.48	1.00							
N	-0.37	-0.68**	0.02	0.86**	1.00						
S	-0.24	-0.58*	-0.11	0.92**	0.99	1.00					
Mn	0.42	0.73**	-0.09	-0.83**	-1.00	-0.98**	1.00				
Zn	0.87**	0.99**	-0.64**	-0.36	-0.78**	-0.69	0.82**	1.00			
Fe	0.87	0.99	-0.64**	-0.36	-0.78	-0.69**	0.82	1.00**	1.00		
Cu	0.84**	0.57*	-0.97**	0.67**	0.21	0.33	-0.15	0.45	0.45	1.00	
P	-1.00**	-0.94	0.93	-0.13	0.39	0.27	-0.45	-0.88**	-0.88	-0.82**	1.00

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Table 2d: Correlation coefficients of Physiochemical Variables for 2010-Year of plantation.

	Depth	*pH*	*MC*	*C*	*N*	*S*	*Mn*	*Zn*	*Fe*	*Cu*	*P*
Depth	1.00										
pH	0.94**	1.00									
MC	-0.37	-0.66**	1.00								
C	-0.88	-0.99**	0.77**	1.00							
N	-0.88**	-0.99	0.76	1.00**	1.00						
S	0.98**	0.99**	-0.57*	-0.96**	-0.96	1.00					
Mn	0.93**	0.75**	0.01	-0.64**	-0.64	0.82	1.00				
Zn	0.87**	0.98**	-0.78**	-1.00**	-1.00	0.96	0.62**	1.00			
Fe	-0.46	-0.14	-0.65**	-0.02	-0.01	-0.25	-0.76	0.04	1.00		
Cu	0.50*	0.76**	-0.99**	-0.85**	-0.85	0.68**	0.14	0.86**	0.54*	1.00	
P	-0.99**	-0.98**	0.48	0.93	0.93	-1.00	-0.87	-0.92**	0.35	-0.60**	1.00

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Discussion:

From Tables 2 (a-d), the following could be deduced from all the years of plantation considered; pH has a strong positive correlation with depth, except for the oil palm plantation cultivated in the year, 2000 which shows that the peat loses its acidity with depth as a result of peat mineralization as shown in Fig 2a. According to Figure 2b and Tables 2a-d, the moisture content shows strong negative and correlation with depth, which means the water content in the soil decreases with depth. This means the soil moisture content at the surface is higher than that below the surface due tothe overburden pressure the soil is subjected to beneath the soil surface which tends to reduce the pore spaces and water holding capacity of the soil at that level. Table 1 shows strong positive correlation between the soil carbon and soil moisture content. This thus explains the reason for theavailability of moisture at the root zone to the plant which further decreases with depth as soil carbon.This therefore explains why peaty nature of the peatland soil reduces with depth as mineral soil beneath the peat soil is approached. Carbon, with the highest content value in the peat soil shows strong negative correlation with depth with coefficient, (r = -0.87) in oil palm cultivated in the year 2000. Carbon also shows negative weak correlation with pH except in 2000-year of plantation and strong positive correlation in 2000 and 2006-year of plantation. The negative correlation of carbon with soil particularly more in 2000 Age of plantation could be as a result of long term farming practices the peatland has been subjected to which has further degraded the peatland. In order words development phase of the peat soil dictates level of degradation expected of the peats. Nitrogen and Sulphur show negative strong correlation with depth which means the parameters decreases with increased depth. This has been attributed to the concentration of these parameters at the near surface soil NSS from the applied fertilizers which are then adsorbed in water and made use by the plant. The remaining parts of the particles not taken by the plants find their ways to the sub-surface in a less concentrated form. Phosphorus shows strong positive correlation with all other parameters except with heavy metals with very weak positive

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correlation. However, Phosphorus shows very strong negative correlation with depth, which means Phosphorus decreases as depth increases. The decrease in Phosphorus concentration with increased depth is also traceable to what happens to nitrogen and sulphur as they come in contact with soil and groundwater. They have higher concentration at NSS due to the applied fertilizer and their concentration reduces with depth as they are being used up by the plants at the root zone. Most of the parameters except Manganese, Mn, has either strong positive or negative correlation with soil moisture content, and all heavy metals considered like, Cu, Mn, Zn, Fe decrease with increased soil moisture content.

Conclusion:

From the results soil analysis in Tables 2 (a-d), the soil has been confirmed to be peat soil to certain depth, (2.5 – 3.0 m), which confirms the peat to be deep peat. The negative correlation between Phosphorus, P, and Nitrogen, N, with depth suggests the result of fertilization of the plantation where the applied fertilizers allow concentration of these parameters at NSS, but decreases with depth. In other words, there is more concentration of P and N at the surface compared to what is obtained deep in the soil. The presence of heavy metals also suggests the accumulation of effects of fertilizers on the plantations over the years. The heavy metals were also observed to be negatively correlated with depth. In overall, the environmental impacts of oil palm plantation with regards to the ages of plantation has been justified as the highest carbon content was discovered in the area where the oil palms were cultivated in the year 2000 (longest period of cultivation in the study area). The results therefore suggest the gradual loss of carbon content from the peatland with time due to oil palm cultivation and this could also trigger climate change effects, if not controlled. Further studies that will look at the annual rate of carbon loss could therefore be of interest in this regard, especially carbon loss in form of dissolved organic carbon, DOC from the peatland through seepage to the nearby drains

REFERENCES

[1] Mutert, E., T.H. Fairhurst and H.R. von Uexküll, 1999. Agronomic Management of Oil Palms on Deep Peat.*Better Crops International Journals* 13(1): 36-38.

[2] Driessen, P.M., 1978. Peat soils. Los BanosPhilippinnes. The International Rice Research Institute (IRRI). In: Soil and Rice. Hlm, pp: 763-779.

[3] Wösten, J.H.M., H.P. andRitzema, 2001. Land and water management options for peatland development in Sarawak, Malaysia. International Peat Journal, 11: 59-66.

[4] Noormahayu, M.N., A.R. Khalid and M.A. Elsadig, 2009. Financial assessment of oil palm cultivation on peatland in Selangor, Malaysia. Mires and Peat, 5(02): 1–18.

[5] Joseph, K.T., K.A. Hamzah and A.M. Rashid, 2013. MALAYSIA Land-Use Change in the Oil Palm Sector.*Available at* http://rt9.rspo.org/pres/pcfinals/pc3/PC3.2_Prof_KT_Joseph.pdf *Retrieved January, 2014*

[6] Van der Werf, G.R., D.C. Morton, R.S. DeFries, J.G.J. Olivier, P.S. Kasibhatla, R.B. Jackson, G.J. Collatzand, J.T. Randerson, 2009. CO_2 emissions from forest loss. *Nature Geoscience*, 2: 737–738.

[7] Zhao, S.Q., L.J. Da, Z.Y. Tang, H.J. Fang, K. Song and J.Y. Fang, 2006. Rapid urban expansion and its ecological consequences in Shanghai, China. Front Ecol Environ, 4: 341–346.

[8] Koh, L.P. and D.S. Wilcove, 2008. *Is oil palm agriculture really destroying tropical biodiversity?* Conservation Letters, 1: 60-64.

[9] John, E., 2005. Fearing the Worst for Borneo.New Straits Times. Retrieved March, 2013 from http://findarticles.com/p/newsarticles/new-straits- mes/mi_8016/is_20050821/fearingborneo/ai_n44303706

[10] Hooijer, A., M. Silvius, H. Wösten and S. Page, 2006. PEAT-CO_2, Assessment of CO_2 emissions from drained peatlands in SE Asia. Delft Hydraulics Report Q3943.

[11] Tanga, Z., B.A. Engela, B.C. Pijanowskib and K.J. Lima, 2005. Forecasting land use change and its environmental impact at a groundwatershed scale. Journal of Environmental Management, 76: 35–45.

[12] Johnson, S.B., J.R. Hosking, R.J. Chinnock and R.H. Holtkamp, 2009. The biology of Australian weeds *Cylindropuntiarosea*(DC.) Backeb.and*Cylindropuntiatunicata*(Lehm.) F.M. Knuth (Cactaceae).*Plant Protection Quarterly*, 24: 42-49.