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Horizontal and Vertical Distribution of Carbon, Nitrogen and Sulfur Concentrations in Sungai Putri Peat Forest, Ketapang District of West Kalimantan Province, Indonesia

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Tropical peat forests are known for significant places for Carbon storage, biodiversity, and freshwater supplies. Tropical peat forests are mostly located in Southeast Asia, particularly in humid tropical climates. Indonesia has the largest tropical peats, ranging from 160,000 to 210,000 Km^2[1]. Peats in Indonesia are largely distributed in coastal region, in the upper river basin, and also in the high altitude. Major islands in Indonesia with important peat deposits are Borneo, Sumatra and Papua. A total of 55 ± 10 Gt carbon is stored in partially decomposed woody biomass of tropical peats in Kalimantan, Sumatra, and West Papua[2]. Tropical peats store between 1,000 and 5,000 tonnes Carbon per hectare[3], and the aboveground carbon in tropical peatland forests ranges from 150 to 300 tonnes Carbon per hectare.

In West Kalimantan Province, tropical peats presently occur in coastal region and in the upper river basins. Major river basins associated with peat formations in this province are the Kapuas River (1086 Km), the Landak River (178 Km), the Pawan River (197 km), the Sambas River (223 km), and the Mempawah River (± 60 km). The estimated peat areas in the West Kalimantan Province are approximately 17,000 km^2[4]. It is estimated that coastal peats extents up to 63% (10,826 km^2), and the rest is inland peats. Inland peats are sometimes called as marginal peat as the distribution of these peats is restricted in the middle and upper river basins. In West Kalimantan, inland peats mainly occur in depression areas from approximately at 100 Km and up to 800 Km from the mouth of the Kapuas River[5]. It is common that inland peat is shallow (< 3 meters depth). The origin inland peats are from freshwater swamp and kerangas (kerapa) forests. Mineral substrates beneath inland peats are purely white sands (quartz) in peats derived from kerangas (kerapa) forests, sandy clay or sandy loam in peats derived from freshwater swamp forests. Coastal peats are mainly originated from mangrove forest[6], and commonly have sulfidic materials in mineral substrates beneath peats.

We aim to estimate both vertical and horizontal distribution of Carbon, Nitrogen and Sulfur from coastal peats of Sungai Putri. The study was conducted in selectively logged-over-coastal peat forest of Sungai Putri, Ketapang District, West Kalimantan Province, Indonesia.

Table 1. Summary of selected properties and relative distribution of C, N and S Concentrations in open peat and peat forest plots

Variable	Site Code	Mean	SD	SE	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
BD	DSP (n=58)	0.100	0.052	0.007	0.086	0.113	0.019	0.293
($g.cm^{-3}$)	W (n=20)	0.092	0.017	0.004	0.084	0.100	0.070	0.148
	E (E=168)	0.076	0.015	0.001	0.073	0.078	0.039	0.125
	X (n=26)	0.092	0.014	0.003	0.086	0.097	0.074	0.125
Grand Mean (n = 272)		0.084	0.029	0.002	0.080	0.087	0.019	0.293
WC	DSP (n=58)	6,174	4,216	554	5,066	7,283	620	20,115
($g.kg^{-1}$)	W (n=20)	6,894	2,457	549	5,745	8,044	2,562	9,589
	E (E=168)	10,334	2,491	192	9,955	10,714	5,959	33,237
	X (n=26)	8,434	1,772	348	7,718	9,150	4,118	11,187
Grand Mean (n = 272)		9,013	3,383	205	8,609	9,417	620	33,237
LOI	DSP (n=58)	689	337	44	600	777	82	995
($g.kg^{-1}$)	W (n=20)	941	118	26	886	997	471	996
	E (E=168)	950	83	6	937	962	503	1,221
	X (n=26)	953	42	8	936	970	854	999
Grand Mean (n = 272)		894	202	12	870	918	82	1,221
C	DSP (n=58)	37.0	19.0	2.5	32.0	42.0	1.5	57.1
(%)	W (n=20)	55.5	3.7	0.8	53.8	57.2	41.0	58.3
	E (E=168)	53.2	4.2	0.3	52.6	53.9	23.9	59.6
	X (n=26)	55.9	1.9	0.4	55.2	56.7	50.1	59.5
Grand Mean (n = 272)		50.2	11.7	0.7	48.8	51.6	1.5	59.6
N	DSP (n=58)	0.7	0.4	0.0	0.6	0.8	0.1	1.9
(%)	W (n=20)	1.0	0.3	0.1	0.9	1.1	0.6	1.8
	E (E=168)	1.1	0.3	0.0	1.0	1.1	0.4	2.5
	X (n=26)	1.0	0.3	0.0	0.9	1.1	0.7	1.5
Grand Mean (n = 272)		1.0	0.3	0.0	0.9	1.0	0.1	2.5
S	DSP (n=58)	0.9	1.0	0.1	0.6	1.1	0.2	4.2
(%)	W (n=20)	0.1	0.2	0.0	0.0	0.2	0.0	0.6
	E (E=168)	0.1	0.1	0.0	0.1	0.2	0.0	1.0
	X (n=26)	0.3	0.3	0.0	0.2	0.4	0.0	0.8
Grand Mean (n = 272)		0.3	0.6	0.0	0.2	0.4	0.0	4.2
C/N Ratio	DSP (n=58)	66	26	3	59	72	27	215
	W (n=20)	68	18	4	60	76	35	121
	E (E=168)	61	12	1	59	63	25	98
	X (n=26)	71	17	3	64	78	41	102
Grand Mean (n = 272)		63	17	1	61	65	25	215
C/S Ratio	DSP (n=58)	283	226	30	223	342	5	636
	W (n=20)	7,061	3,829	856	5,269	8,853	197	15,549
	E (E=168)	2,163	1,726	133	1,900	2,426	135	5,926
	X (n=26)	2,860	3,446	676	1,468	4,251	178	12,587
Grand Mean (n = 272)		2,189	2,558	155	1,883	2,494	5	15,549
N/S Ratio	DSP (n=58)	4.4	3.5	0.5	3.5	5.4	0.1	10.5
	W (n=20)	110.6	63.9	14.3	80.7	140.5	2.9	216.8
	E (E=168)	36.8	30.5	2.4	32.1	41.4	1.9	130.4
	X (n=26)	41.1	53.4	10.5	19.5	62.7	3.3	187.0
Grand Mean (n = 272)		35.7	41.9	2.5	30.7	40.7	0.1	216.8
pH(H_2O)	DSP (n=58)	3.9	0.4	0.1	3.8	4.1	3.4	5.6
	W (n=20)	3.9	0.2	0.1	3.8	4.1	3.6	4.7
	E (E=168)	3.8	0.4	0.0	3.7	3.8	2.9	4.9
	X (n=26)	3.9	0.5	0.1	3.6	4.1	3.1	4.6
Grand Mean (n = 272)		3.8	0.4	0.0	3.8	3.9	2.9	5.6
pH(KCl)	DSP (n=58)	3.3	0.6	0.1	3.1	3.4	2.5	4.8
	W (n=20)	3.5	0.2	0.0	3.4	3.6	3.2	4.0
	E (E=168)	2.8	0.2	0.0	2.8	2.9	2.5	3.8
	X (n=26)	3.1	0.5	0.1	2.9	3.3	2.6	4.1
Grand Mean (n = 272)		3.0	0.4	0.0	3.0	3.1	2.5	4.8
CD	DSP (n=58)	725	510	67	591	859	65	2,021
($t.ha^{-1}$)	W (n=20)	1,494	1,060	237	998	1,990	235	3,805
	E (E=168)	1,927	1,217	94	1,742	2,113	96	5,103
	X (n=26)	2,044	1,259	247	1,536	2,553	193	4,326
Grand Mean (n = 272)		1,650	1,200	73	1,507	1,794	65	5,103

Note: DSP (Disturbed and open peat sites); West Transect (Forest Sites); East Transect (Forest Sites); X = Central Transect (Forest Sites)

BD = ash free bulk density ($g.cm^{-3}$); LOI = Loss on Ignition ($g.kg^{-1}$); WC = Water Content ($g.kg^{-1}$) CD = Carbon density ($t.ha^{-1}$)

The Sungai Putri peat dome covers approximately 570 Km^2. This forest is presently threatened by converting into oil palm plantation, fires and fast growing tree species for pulp and paper industry. The forest has a number of endangered species (i.e. orangutan, *Pongo pygmaeus wurmbii*). The Sungai Putri peat forest is considered to be a potential site for Reducing Emission from Deforestation and Degradation (REDD) project.

We conducted fairly intensive peat depth measurements. We made West-East Transect (about 30 Km) and North-South Transect (about 23 Km) in forest site, and 23 peat cores in open peat site. We measured peat and water table depths every kilometer. We took peat core samples with Eijkelkamp peat sampler, and analyzed bulk density, water content, loss on ignition, pH, and concentrations of organic Carbon, Nitrogen and Sulfur at a 50 cm interval. The total numbers of analyzed subsamples are 272.

The Sungai Putri peat probably consists of several peat domes, which might indicate several phases of peat formations or intermittent peat accumulations. We recorded peat depths in West East Transect from 3.5 to 14.5 meters and in North-South Transect from 1.7 to 10.5 meters (Figure 1). In open peat plots, peat depths range from 20 cm to 8 meter. Deep peat is found in the recent clearance of disturbed sites. At the time of sample campaigns (June 2008, August 2008 and November 2008), we recorded water table depths in West part ranged from -4.5 to -38 cm, in East part ranged from -21 to -58 cm, and in North part ranged from -3 to -26 cm, and in South part ranged from +4 to -34 cm. In open peats, the water table depths ranged from -5 to 90 cm.

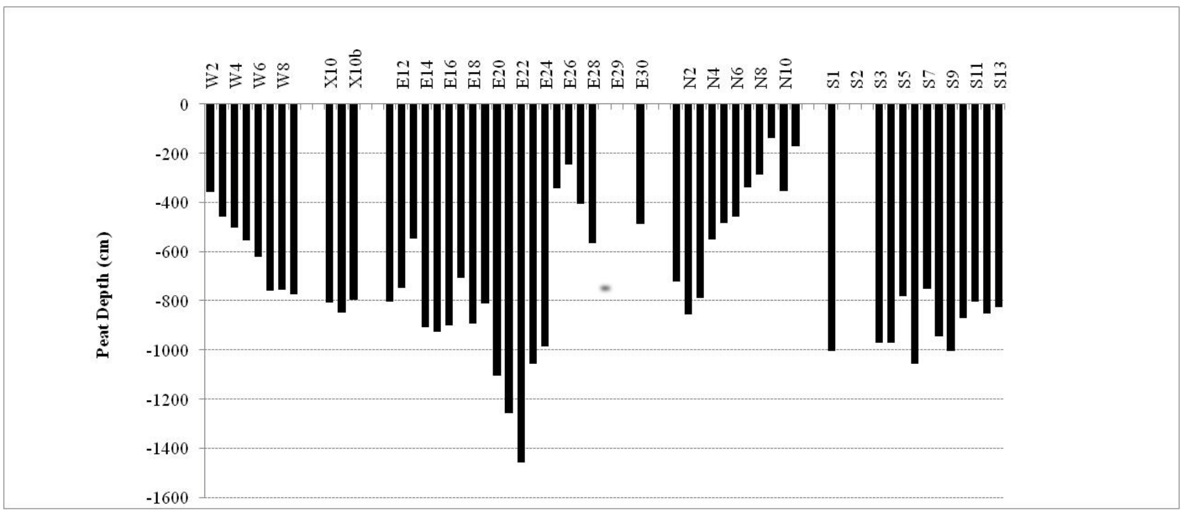

Fig. 1. A record of peat depths in Sungai Putri Peat Forest (W= West Plot; X = Central Plot; E = East Plot; N = North Plot; S = South Plot)

The major properties of these peats are low in bulk density, pH and ash residue (after 550 ºC ignition for 5 hours), and high water content. Total organic Carbon (TOC) in peat forests ranged from 24 to 60%, total Nitrogen and sulfur (TN and TS) are remarkably low. Carbon concentrations in open peats show significant decline and an increase in Sulfur (See Table 1). These differences are statistically significant according to Dunnett T3 test[7]. The decline of Carbon fraction in open peat is resulted from peat decomposition. We thought the variability of water table depths must have a major role in reducing organic Carbon and rising Sulfur in open peat site. For agricultural uses, peat forest is commonly removed and drained. Peat forest clearance and drainage lead to deliberate fall of water table depths that enhance peat decays, and definitely end peat accumulation. The more thickness of active layer (acrotelm) in peat profiles the more Carbon loss in the forms of atmospheric CO_2 and Dissolved Organic Carbon and Particulate Organic Carbon (DOC and POC) through water transport.

Values of bulk density, pH, water content, ash, and TOC, TN and TS concentrations relative to peat depths are indifference in peat forest. In contrast, open peats shows significant variability relative to depths in Carbon, Nitrogen, Sulfur, bulk density, loss on ignition, water content, and pH. Accumulative Carbon densities relative to depths in forest plots seem to be as much twice as higher than of open peats (Figure 2).

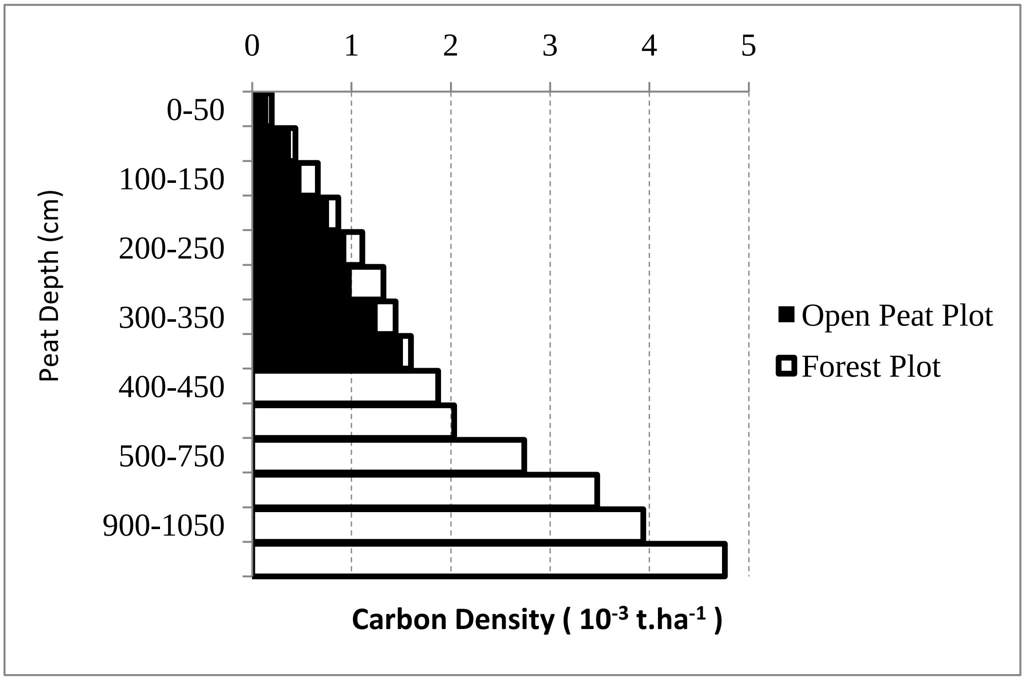

Fig. 2. The accumulative Carbon Density relative to depths in of open peat and forest plots

We reckoned that these coastal peats were formed in mid Holocene[8], and originated from mangrove forest[6]. In contrast, inland peats are much early formed (>30,000 ^{14}C y BP).[9,10] An estimated peat accumulation rate is 1 – 2 mm per year[11]. We predicted that Long Term Carbon Accumulation Rate (LORCA) in this peat complex may probably fall between 0.4 and 0.8 t C ha^{-1}.y^{-1}[5]. It is not so sure that this peat would survive under the present disturbances related to global climate change and economic development program. The most important threat is activities of humans, who commonly view peat forest as naturally unproductive. That is why the majority of peat forests suffer from land use conversion. Ecological functions of peat forest as Carbon store and geological source of organic rock are mainly uncounted.

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