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Characterizing the cultivated lowland peat soils in two physiography positions in Kalimantan, Indonesia

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Abstract

The large lowland peat soils of Indonesia are distributed in various physiographic positions in Sumatra, Kalimantan and Papua islands and have important role in contributing carbon emission. The objective of this study was to characterize the physical and chemical properties of cultivated lowland peat soils in two experimental sites in Kalimantan. Site-1 (5.01 ha) was in Central Kalimantan at the margin of peat dome cultivated with rubber plantation, whereas site-2 (6.72 ha) was in South Kalimantan at the alluvial depression cultivated with paddy rice and maize. Eight representative peat soil profiles from the detailed soil mapping of both sites were selected and 43 soil samples were analyzed for physical and chemical properties. The results indicated that the peat soils of both sites showed different properties in term of degree of decomposition, thickness, ash content, soil acidity, and depth of water table. In site-1, the peat decomposition varied from hemic to sapric with thickness of 5.2-7.0 m and deep water table, while in site-2 the peat decomposition was mostly fibric with thickness of 0.6-2.3 m and shallow water table. The soil bulk density of site-1 was higher than those of site-2 and correlated to fiber content (R^2=0.45). The ash contents of sites-1 were lower than those of site-2 and correlated to organic C content (R^2=0.68 and 0.89). The soil pH of both sites was very strongly acid, however, in site-1 it was more acid (pH 3.4-3.7) than of site-2 (pH 3.9-4.7) indicating these soils were low content of exchangeable bases. These soils of both sites were grouped as ombrogenous peat, since they showed low ash content, low nutrient content and very acid reaction. This study also showed that physiographic position influences the properties of peat soils, and consequently it would influence the magnitude of carbon stocks and carbon emission.

Keywords: Ash content, fiber content, ombrogenous peat, peat dome, Kalimantan.

INTRODUCTION

Indonesia has the largest area of tropical lowland peat soils in the world. Previously, the total area of peat soils in Indonesia is estimated 17.0 million ha (Polak, 1950; Soepraptohardjo and Driessen, 1976; Soekardi and Hidayat, 1994). Recent study shows that the area of peat soils decrease and are estimated about 14.9 million ha or 7.8 % of the total Indonesian land surface (Ritung et al., 2011). The most extensively occurrence is in the eastern plains of Sumatra, western and southern plains of Kalimantan, and southern plains of Papua. Peat soils as known as Organosols (Dudal and Soepraptohardjo, 1957) or Histosols (FAO, 1989; Soil Survey Staff, 2010) are the soils having a thickness of 40 cm or more that formed from organic matter deposit in saturated environmental condition. The organic matter deposits come from plant residues or plant tissues which have already fully or partially decayed.

The occurrence of peat soils were recognized in different physiographic positions that caused different properties. They may be in coastal area, inland basins, or between those two physiographic positions. Sumatra and Kalimantan lowland peat soils started to accumulate on the flat coastal “clay blanket” not more than 4,000 to 4,500 years ago when the rise of sea level that followed the last glacial period slowed down (Van Wijk, 1951; Verstappen, 1975). Based on the carbon dating, the ombrogenous peat domes were formed in the last 5,000 years (Driessen and Subagjo, 1975). In Serawak Malaysia, these soils were formed in 4,300 years ago (Andriesse, 1988). Most of Indonesian peat soils are formed in low altitude coastal and sub-coastal region (Rieley and Page, 2005).

These soils have unique properties, such as low bulk density, high porosity, high subsidence after drained, low bearing capacity, irreversible shrinkage, higher oxidation and decomposition processes after drained, and susceptible to erosion if dry (Driessen and Suhardjo, 1976; Widjaja Adhi, 1997). The degree of peat decomposition can be divided into three kinds based on the fiber content, namely: (a) fibric, least decayed organic matters containing 75% fiber or more, (b) hemic (halfy decayed) containing 17 to 74% fiber, and (c) sapric, fully decayed with fiber content of less than 17% (Soil Survey Staff, 2010). Related to fertility status, peat soils could be divided based on nutrient and ash content into eutropic, mesotropic and oligotropic (Driessen and Sudjadi, 1984; Widjaja Adhi, 1988). According to formation process, the peat soils could be divided into topogenous and ombrogenous peat soils (Polak, 1950), where the topogenous peat soils were more fertile than the ombrogenous peat soils as indicated by higher ash content (>10%). Driessen and Rochimah (1976) reported that bulk density of lowland peat soils in West Kalimantan under natural vegetation ranged from 0.08 to 0.23 g cm^{-3} and in Central Kalimantan ranged from 0.10 to 0.18 g cm^{-3}. Suhardjo and Widjaja Adhi (1976) found that chemical properties of shallow peat soils in Riau Sumatra are better than the deep peat soils. Related to agriculture use, the peat thickness might be divided into four classes, namely shallow (<1 m), medium (1-2 m), thick (2-3 m) and very thick (>3 m). The shallow to medium thickness, hemic to sapric decomposition, and clayey substratum could be recommended as suitable peat land for agricultural use (Widjaja Adhi, 1988; Agus and Subiksa, 2008).

The objective of the study was to characterize the physical and chemical properties of cultivated peat soils in two experimental sites of different physiographic position in Central and South Kalimantan Provinces, for supporting a baseline for carbon emission assessment of cultivated peat soils organized by Indonesia Climate Change Trust Fund (ICCTF).

MATERIAL AND METHOD

Site description

Fieldwork was executed in both sites in December 2010-February 2011. Site-1 (5.01 ha) was located about 45 km south of Palangkaraya, Central Kalimantan, at latitude 2^o 30’ 55” S and longitude 114^o 10’ 12” E. The physiographic position of site-1 was the margin of peat dome and cultivated with rubber plantation. Site-2 (6.72 ha) was located about 40 km east of Banjarmasin, South Kalimantan, at latitude 3^o 25’ 55” S and longitude 114^o 46’ 2” E (Figure 1). The physiographic position of site-2 was the alluvial depression and cultivated with paddy rice.

The mean annual rainfall of the area ranged from 2,496 mm (Palangkaraya station) to 2,605 mm (Banjarmasin station) with number of consecutive wet months ($\geq$200 mm) was 5-6 months and number of dry months (<100 mm) was < 2 months. The mean monthly air temperature and relative humidity at Palangkaraya station varied from 26.3 to 27.3 °C and from 75 to 86% respectively (Hidayat et al., 2011).

Soil sampling and analyses

Fieldwork was conducted by executing detailed soil mapping in both sites. Soil observation used grid system at spacing of 25 x 50 m, and used specific peat soil auger of *Eijkelkamp* model. Soil morphological properties were described according to Guideline for Soil Profile Description (FAO, 1990). Geographic position of each observation was measured by GPS tool and plotted on to map. Eight representative soil profiles consisting of 43 samples were selected for physical and chemical analyses conducted in the laboratory of the Indonesian Soil Research Institute (Eviati and Sulaeman, 2009).

The soil physical and chemical analyses consisted of bulk density (BD), moisture content, fiber and ash content, pH-H_2O, electrical conductivity (EC), organic matter content (C, N and C/N), content of P_2O_5 and K_2O (extracted with HCl 25%), exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+), cation exchange capacity (CEC) and exchangeable acidity (Al^{3+} and H^+) in KCl 1N. These soils were classified according to Soil Taxonomy (Soil Survey Staff, 2010) into subgroup level. Carbon stock of peat soils was estimated by calculating the equation: [Cs = A x D x BD x C], where Cs = carbon stock (in ton), A = area of soil mapping unit (in m^2), D = thickness (in m), BD = bulk density (g cm^{-3} equal to t m^{-3}), and C = % organic carbon content (Agus et al., 2011).

RESULTS AND DISCUSSION

Morphological and physical characteristics

The peat soils were generally very dark color in both sites, indicating of high organic matter contents. Surface soil colors varied from black and very dark brown (10YR2/1-7.5YR3/2) to very dusky red (2.5YR 2.5/2) in moist condition, while subsurface soil colors changed somewhat lighter to dark brown (7.5YR3/3-5YR3/2) and dusky red (5YR3/3). In transition to mineral soils, the colors were lighter because of mixture with mineral soils. The colors of mineral soils were generally light to dark gray (2.5Y6/2-7/1; 5Y5/1; 10YR7/2; 10YR4/1) and clayey texture. In subsurface soils a lot of plant residues were still recognized, especially in site-2. The peat thickness

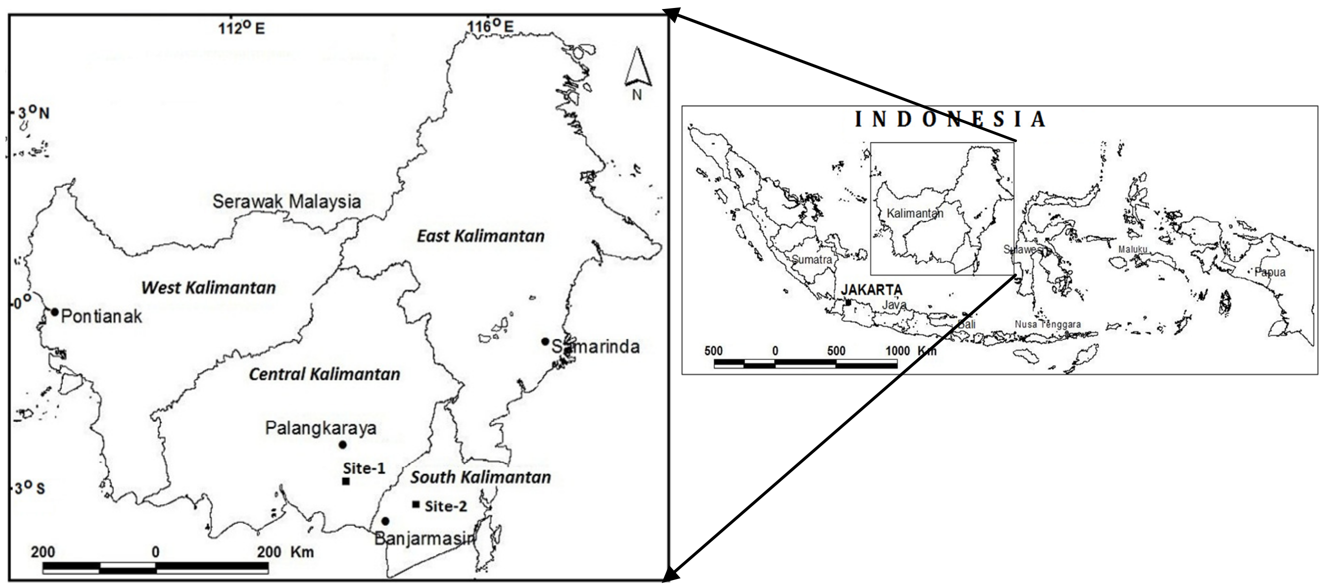

Figure 1. Location of the study area

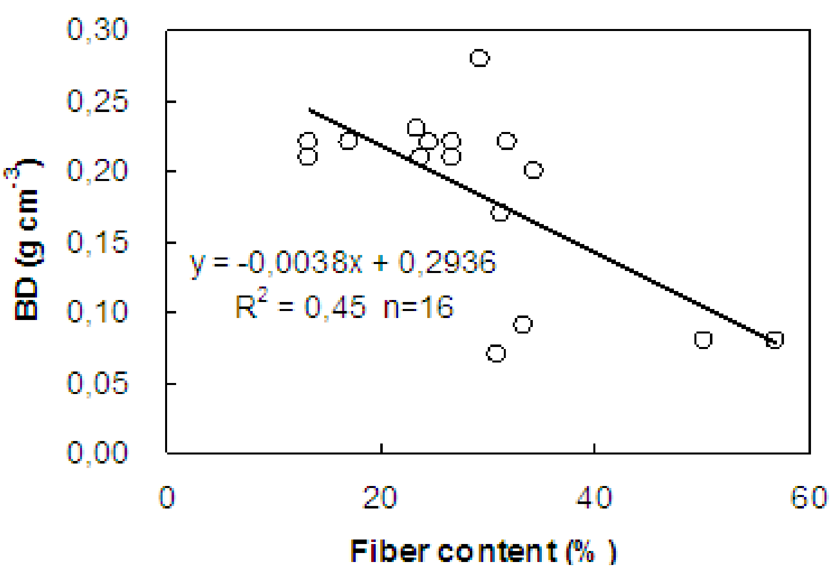

Figure 2. The relation of fiber content to soil BD of both sites

varied depends on the physiographic position. In the margin of peat dome (site-1) the thickness varied from 5.2 to 7.0 m, which was exactly different compared to the alluvial depression (site-2) having thickness of 0.6 to 2.3 m.

The degree of peat decomposition showed that the fiber content in site-1 varied from 13 to 23% in the surface soils, and 17 to 43% in the subsurface soils, and tends to increase with depth, indicating the surface soils were more decomposed because of more drained condition (water table 45-50 cm depth). In site-2 the fiber content varied from 24 to 34% in the surface soils and from 19 to 57% in the subsurface soils, which was higher than those of the site-1. Based on the fiber content, the degree of peat decomposition in site-1 was hemic to sapric, while in site-2 was hemic (Soil Survey Staff, 2010). However, based on field observation the degree of peat decomposition of both sites was exactly different. In site-1, it was sapric in the surface soils and hemic in the subsurface soils, whereas in site-2, it was clearly hemic in the surface soils and fibric in the subsurface soils. The fiber content of peat soils of both sites showed negative relationship to soil BD (R^2=0.45) as presented in Figure 2.

In site-1, the soil BD of hemic and sapric maturity varied from 0.21 to 0.23 g cm^{-3}, while in site-2 it varied from 0.17 to 0.22 g cm^{-3} for hemic maturity of the surface soils, and 0.07 to 0.09 g cm^{-3} for fibric maturity of the subsurface soils (Table 1). The BD values of the surface soils were higher than the subsurface soils, because the surface soils were more decomposed and compressed, as affected by oxidized zones and soil tillage. Similar results of the BD-values were obtained from West and Central Kalimantan which ranged between 0.08-0.23 and 0.11-0.18 g cm^{-3} respectively (Driessen and Rochimah, 1976). Recent study shows that average of peat soil BD in Kalimantan is 0.07, 0.17, and 0.20 g cm^{-3} for fibric, hemic and sapric maturity respectively (Wahyunto et al., 2010). In general, the peat soil BD has closely related to the degree of peat maturity, where fibric peat maturity has very low BD, mostly < 0.10 g cm^{-3}, for sapric maturity was >0.20 g cm^{-3}, and for hemic maturity is in between of 0.10-0.20 g cm^{-3} (Andriesse, 1974).

Moisture content in dry weight condition varied from 73 to 79% in site-1, and 78 to 93% in site-2. In wet condition, the moisture content was very high which ranged from 265 to 373% in site-1, and 364 to 1,409% in site-2. The data showed that moisture content of peat soils in site-2 was higher than site-1, because the peat soils were less decomposed. Mutalib et al. (1991) reported that the moisture content of peat soils varied between 100 to 1,300% of the dry weight of the soils. It means that peat soils can absorb water as much as 13 times of their weight. The higher content of water causes low BD and the soils become soft and low bearing capacity (Nugroho et al., 1997; Widjaja Adhi, 1997). Water table of site-1 was deeper (at 45-50 cm depth) and more drained, and therefore the soils were more oxidized and decomposed compared to the water table of site-2 (at 5-10 cm depth).

Chemical characteristics

The peat soil pH of both sites was generally very strongly acid (pH<4.7). In site-1, the soil pH was more acid which ranged from 3.4 to 4.4 throughout the soil horizons compared to the soil pH of site-2 (pH 3.9-4.7). The pH of the mineral soils (substratum) was higher than the pH of peat soils, which varied from 4.2-4.4 in site-1 and 4.1-4.7 in site-2. The electrical conductivity (EC) values of both peat soils and mineral soils were very low (<4 dS m^{-1}) throughout the soil horizons for all the profiles, indicating that there was no effect of salt intrusion or tidal influence.

The soil organic carbon contents were very high in all the profiles. In site-1 the organic carbon varied from 31.28 to 57.59%, while in site-2 it varied from 25.05 to 55.61%. The organic carbon content tended to increase with depth and subsequently it decreased close to the mineral soils (substratum). It indicated that the surface soils were more decomposed and more mineralized than the subsurface soils. The C/N ratios were also very high which varied from 25 to 68, indicating N nutrient less available to plant.

The ash contents were generally low (<10%) for both sites, indicating there was no mineral enrichment, except in the transition to mineral soils (substratum) their contents were increased (>10%), because of mixture with mineral soils. Also, the ash content of the surface soils of site-2 was also higher than the subsurface soils, as might be the effect of soil management, such as tillage and burning, during the preparation of crop planting. The ash content and organic carbon of peat soils showed significant relationship with R^2 = 68 and 89 for site-1 and site-2 respectively (Figure 3).

In both sites, the nutrient content of extractable P_2O_5 (HCl 25%) was low to very low, and extractable K_2O (HCl 25%) was low to medium, and decreased within depth (Table 2). The exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) and base saturation were also low and decreased with soil depth. The values of exchangeable bases were generally in the order of Ca^{2+} > Mg^{2+} > K^+ or Na^+ indicating there was no tidal or salt influence (Widjaja Adhi, 1988). In each profile there was a horizon with higher exchangeable Na^+ than the other exchangeable cations, but it was not the effect of salt intrusion, because the EC values were low. The exchangeable acidity ($Al^{3+}$and H^+) was high and increased with depth in both sites, indicating the soils contained high organic acid. The low content of nutrient and exchangeable cations showed that the peat soils were lesser fertile with increasing depth. These soils only receive nutrients supply from rainfall or atmosphere, and therefore the soils were grouped as ombrogenous peat (Driessen and Sudjadi, 1984). The soil CEC was very high and dominantly affected by organic matter content as indicated by positive relationship between organic C and soil CEC of both sites (R^2 = 0.80 and 0.89) as shown in Figure 4.

Soil classification

Peat soils are classified as Histosols order (Soil Survey Staff, 2010) which is based on the degree of decomposition and the thickness of soil organic materials within the control section. The control section was 130 cm from the surface of hemic or sapric decomposition, and 160 cm for fibric decomposition. The control section was composed of surface tier (30 cm for hemic and sapric, and 60 cm for fibric), subsurface tier (60 cm) and bottom tier (40 cm). The subsurface tier might be considered to classify these peat soils into suborder and great group level. Based on these criteria, the peat soils in the site-1 were hemic to sapric decomposition and could be classified into subgroup level as Sapric Haplohemists (Profiles HK4 and HF 11), Hemic Haplosaprists (Profile UY13), and Typic Haplosaprists (profile HK7); while in the site-2 the soils were dominated by fibric decomposition and could be classified as Hemic

Table 1. Selected morphological and physical properties of peat soils in the study area

Profile code	Horizon depth	Matrix color moist/wet	Field maturity /texture	Fiber content	Moisture content		Bulk density	Water table
					Dry	Wet		
	cm			%	---%---		g cm^{-3}	cm
Site-1 (Central Kalimantan)								
HF11	0-26	2.5YR2.5/2	Sapric	13.2	79	379	0.21	50
	26-110	2.5YR2.5/2	Hemic	29.3	73	263	0.23	
	110-280	5YR3/3	Hemic	41.9				
	280-520	5YR3/3	Hemic	25.5				
	520-570	5Y5/1	Clay	-				
UY13	0-23	7.5YR3/2	Hemic	23.3	77	335	0.23	45
	23-200	2.5YR3/2	Sapric	17.1	78	354	0.22	
	200-340	2.5YR2.5/2	Hemic	31.6				
	340-650	5YR2.5/2	Hemic	27.9				
	650-700	2.5Y6/2	Clay	-				
HK7	0-30	5YR3/3	Sapric	13.6	78	354	0.22	47
	30-70	5YR3/3	Hemic	16.5	79	373	0.21	
	70-100	2.5YR2.5/3	Hemic	43.2				
	100-680	5YR3/3	Hemic	34.2				
	680-700	2.5Y6/1	Clay	-				
HK4	0-25	10YR 2/1	Sapric	13.2	78	350	0.22	46
	25-60	2.5YR2.5/2	Hemic	31.8	78	345	0.22	
	60-120	2.5YR2.5/3	Hemic	30.4				
	120-700	2.5YR2.5/2	Hemic	39.0				
	700-720	2.5Y6/2	Clay	-				
Site-2 (South Kalimantan)								
HK6	0-9	10YR2/1	Hemic	34.2	80	393	0.20	5
	9-57	7.5YR4/3	Fibric	33.3	92	1059	0.09	
	57-62	10YR2/1	Hemic	36.4				
	62-130	2.5Y6/1	Sandy clay	-				
	130-150	2.5Y5/4	Sandy clay	-				
HK3	0-9	10YR2/1	Hemic	24.4	78	364	0.22	10
	9-75	7.5YR4/3	Fibric	56.7	92	1128	0.08	
	75-80	10YR2/1	Hemic	28.6				
	80-135	7.5YR4/3	Fibric	37.0				
	135-143	10YR2/1	Hemic	23.8				
	143-200	2.5Y7/1	Sandy clay	-				
SL12	0-5	10YR2/2	Hemic	23.7	79	377	0.21	10
	5-75	7.5YR3/3	Fibric	50.0	92	1158	0.08	
	75-85	10YR3/2	Hemic	31.0				
	85-170	10YR4/2	Fibric	23.8				
	170-180	10YR3/3	Hemic	28.9				
	180-200	2.5Y6/1	Sandy clay	-				
SL9	0-10	10YR3/2	Hemic	31.1	83	472	0.17	5
	10-60	7.5YR3/3	Fibric	30.8	93	1409	0.07	
	60-75	10YR2/1	Hemic	18.8				
	75-220	7.5YR3/3	Fibric	36.6				
	220-230	10YR3/3	Hemic	16.7				
	230-250	2.5Y6/1	Sandy clay	-				

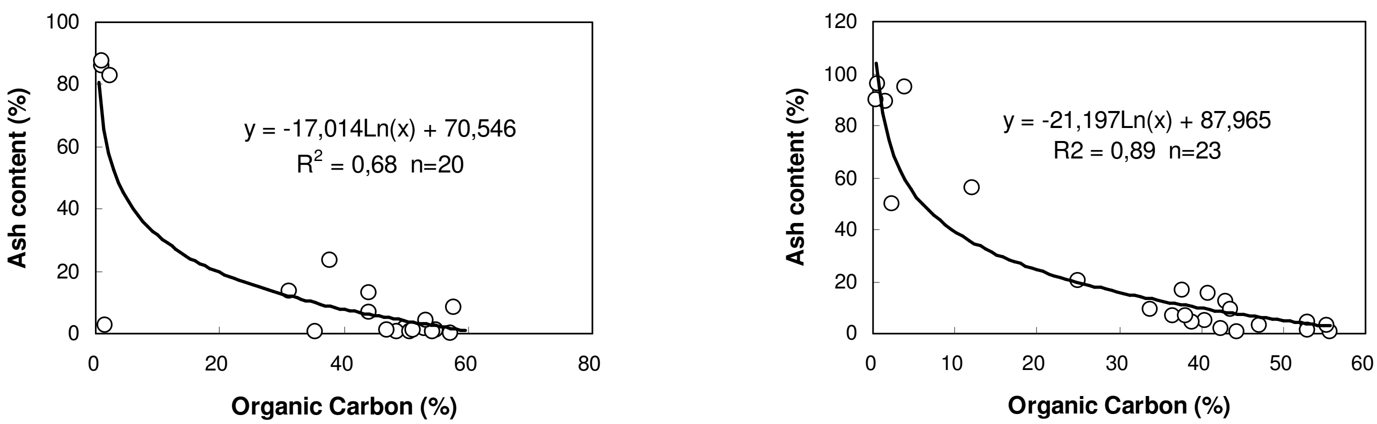

Figure 3. The relation of organic carbon to ash content in site-1 (left) and site-2 (right)

Table 2. Soil pH, electrical conductivity (EC), organic matter content, ash content and potential P and K of peat soils in the study area

Profile code	Horizon depth	pH H_2O	EC	Organic matter			Ash	Extract. HCl 25%	
				C	N	C/N	content	P_2O_5	K_2O
	cm		dS m^{-1}	--- % ---			%	mg 100 g^{-1}	
Site-1 (Central Kalimantan)									
HF11	0-26	3.6	0.12	51.22	0.87	59	1.3	25	13
	26-110	3.6	0.11	54.24	0.90	60	0.7	10	26
	110-280	3.4	0.44	53.17	0.79	67	4.3	4	12
	280-520	4.0	0.05	44.10	0.78	57	13.0	4	8
	520-570	4.3	0.03	2.37	0.21	11	82.6	7	2
UY13	0-23	3.6	0.10	46.91	0.81	58	0.8	17	6
	23-200	3.4	0.23	50.70	1.00	51	0.5	15	14
	200-340	3.6	0.16	54.85	1.78	31	0.9	2	18
	340-650	3.5	0.23	31.28	0.67	47	13.6	3	21
	650-700	4.4	0.02	1.48	0.13	11	2.6	6	2
HK7	0-30	3.7	0.08	49.72	0.77	65	1.4	17	13
	30-70	3.4	0.23	48.51	0.84	58	0.5	14	12
	70-100	3.5	0.17	53.05	0.81	65	1.7	7	15
	100-680	3.6	0.37	37.74	0.63	60	23.6	2	12
	680-700	4.3	0.02	1.15	0.09	13	87.3	7	2
HK4	0-25	3.6	0.08	35.39	0.66	54	0.7	13	8
	25-60	3.5	0.13	57.26	0.84	68	0.1	14	13
	60-120	3.4	0.20	57.59	0.88	65	8.5	7	8
	120-700	3.7	0.10	44.19	0.65	68	6.5	4	13
	700-720	4.2	0.02	0.99	0.09	11	86.0	6	2
Site-2 (South Kalimantan)									
HK6	0-9	4.3	0.04	33.75	2.94	11	9.1	16	10
	9-57	3.9	0.26	38.93	1.34	29	4.1	5	5
	57-62	4.3	0.06	12.17	0.29	42	56.1	12	3
	62-130	4.3	0.02	0.54	0.05	11	96.1	1	3
	130-150	4.7	0.01	0.47	0.04	12	89.8	7	2
HK3	0-9	4.0	0.10	42.92	1.69	25	12.5	26	8
	9-75	4.2	0.07	55.61	1.14	49	1.6	5	20
	75-80	4.0	0.11	52.97	0.85	62	4.3	6	9
	80-135	3.9	0.31	40.42	0.93	43	4.8	3	4
	135-143	4.1	0.08	36.62	1.28	29	6.5	5	5

Table 2. Continuation

	143-200	4.1	0.04	1.55	0.11	14	89.4	1	2
SL12	0-5	3.9	0.38	37.79	1.36	28	16.9	19	17
	5-75	4.0	0.07	53.01	0.95	56	1.2	9	11
	75-85	4.1	0.13	55.37	0.92	60	3.2	5	13
	85-170	4.2	0.08	42.34	0.94	45	2.1	4	13
	170-180	4.0	0.12	40.81	0.72	57	15.3	5	10
	180-200	4.2	0.03	3.83	0.31	12	94.5	4	3
SL9	0-10	4.7	0.11	43.57	1.47	30	9.1	28	7
	10-60	4.3	0.07	47.19	1.20	39	3.3	12	11
	60-75	4.0	0.04	38.02	1.06	36	6.6	9	9
	75-220	3.9	0.16	44.32	0.98	45	0.8	7	20
	220-230	4.1	0.16	25.05	0.51	49	20.3	7	11
	230-250	4.4	0.02	2.27	0.21	11	49.9	4	4

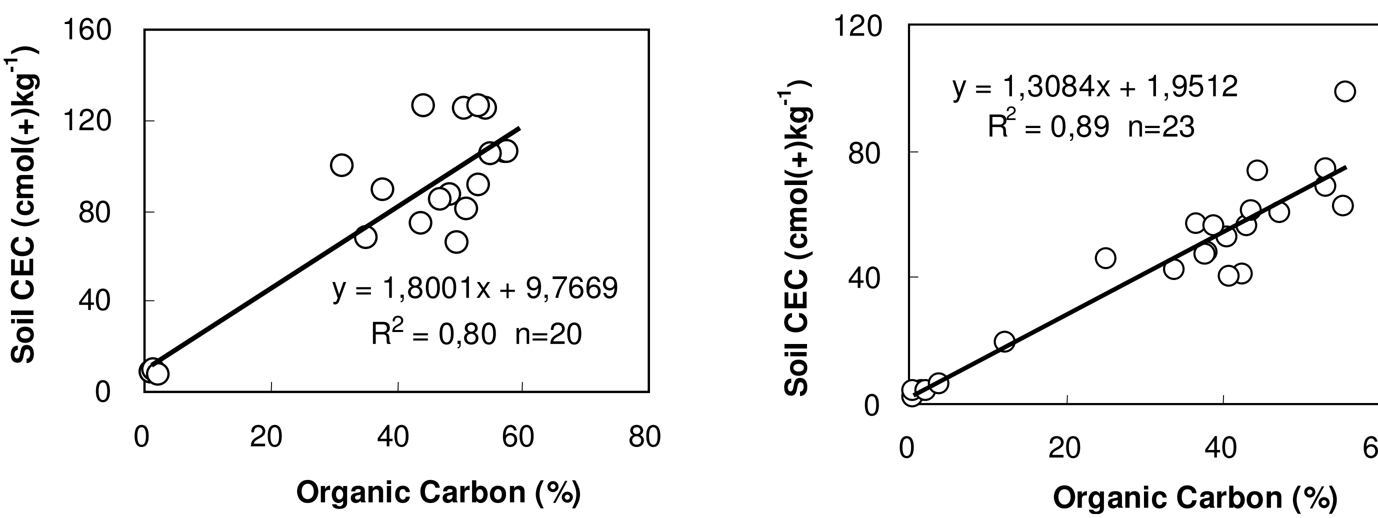

Figure 4. The relation of organic C to soil CEC in site-1 (left) and site-2(right)

Haplofibrists (Profile HK3 and SL9) and Typic Haplofibrists (Profile SL12 and HK6).

Estimation of carbon stock

Estimation of carbon stock of peat soils in both sites was calculated using the equation of Agus et al. (2011). Based on the calculation using the area extent of soil mapping units from the detailed soil maps of both sites (Hidayat et al., 2011), the peat thickness, bulk density, and organic C, the total carbon stock in site-1 was estimated as much as 26,405 ton for 5.01 ha, or equal to 5,270 t C ha^{-1}. Meanwhile in the site-2 the total carbon stock was 3,775 ton for 6.72 ha or equal to 562 t C ha^{-1} which was too low compared to the site-1 (Table 4). This data indicated that peat soils in site-1 would produce higher carbon emission than those soils of site-2.

CONCLUSION

This study showed that the physiographic positions influence peat soil properties in the terms of thickness, degree of decomposition (fiber content), bulk density, ash content, and soil acidity. Therefore, the physiographic position of peat soils of an area must be well understood. Although the peat soil properties of both sites are different, they are grouped as the same type as ombrogenous peat, as indicated by low ash content, low nutrient status and very acid reaction. However, those peat soils of the alluvial depression are slightly higher in ash content and soil pH compared to those peat soils of the margin of dome.

Table 3. Exchangeable cations and exchangeable acidity of peat soils in the study area

Profile code	Horizon depth	Exchangeable cations (NH4OAc pH 7)						Exch. acidity	
		Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Base sat.	Al^{3+}	H^{+}
	cm	------------------- cmol(+)kg^{-1} ------------------					%	-- cmol(+)kg^{-1} --	
Site-1 (Central Kalimantan)									
HF11	0-26	2.37	1.86	0.18	0.16	81	6	1.14	6.14
	26-110	4.01	2.67	0.52	0.93	125	6	2.36	10.90
	110-280	1,69	1.63	0.24	6.22	126	8	14.64	5.94
	280-520	1.30	0.24	0.15	0.41	75	3	16.86	2.36
	520-570	0.72	0.93	0.03	0.12	7	26	4.24	3.42
UY13	0-23	2.12	1.26	0.04	0.21	85	4	1.22	7.95
	23-200	4.09	2.36	0.28	2.12	125	7	2.22	10.95
	200-340	1.87	1.89	0.36	3.29	105	7	7.19	12.97
	340-650	0.82	0.42	0.31	0.25	100	2	17.65	2.91
	650-700	0.63	0.87	0.03	0.12	10	17	3.37	4.00
HK7	0-30	3.42	1.56	0.15	0.28	66	8	1.36	5.56
	30-70	4.09	1.82	0.19	2.62	86	10	1.84	10.87
	70-100	1.66	1.19	0.22	1.34	92	5	5.29	8.53
	100-680	0.88	0.39	0.18	2.03	89	4	18.83	2.07
	680-700	0.74	1.13	0.03	0.10	8	24	2.39	2.97
HK4	0-25	2.55	1.24	0.12	0.33	68	6	1.33	6.70
	25-60	3.50	1.54	0.17	1.87	105	7	1.89	12.24
	60-120	1.98	0.87	0.10	2.20	106	5	8.04	10.04
	120-700	0.93	0.46	0.22	1.12	127	2	17.72	4.57
	700-720	0.78	0.97	0.03	0.07	8	23	3.17	3.14
Site-2 (South Kalimantan)									
HK6	0-9	1.62	0.39	0.19	0.33	43	6	6.90	1.05
	9-57	3.32	1.52	0.10	2.51	56	13	4.15	1.96
	57-62	1.28	0.47	0.04	0.10	19	10	3.86	0.44
	62-130	0.24	0.13	0.05	0.09	2	26	1.00	0.59
	130-150	0.37	0.18	0.03	0.07	4	16	1.05	0.85
HK3	0-9	1.42	0.41	0.07	0.35	56	4	4.68	1.26
	9-75	6.77	2.08	0.40	2.13	98	12	5.73	3.76
	75-80	1.21	1.55	0.18	1.40	68	6	12.62	2.38
	80-135	0.81	0.89	0.08	1.74	53	7	6.08	3.13
	135-143	1.70	0.57	0.10	0.45	57	5	5.29	3.70
	143-200	0.49	0.24	0.03	0.14	4	23	1.66	1.53
SL12	0-5	0.93	0.90	0.30	1.58	47	8	6.16	1.49
	5-75	3.64	2.57	0.22	0.80	74	10	5.40	3.88
	75-85	1.31	1.46	0.26	1.23	63	7	8.89	2.39
	85-170	1.26	0.88	0.25	0.39	41	7	6.20	2.63
	170-180	0.81	1.11	0.19	1.06	40	8	5.24	1.73
	180-200	0.70	0.48	0.05	0.32	6	25	2.24	2.94
SL9	0-10	21.21	1.99	0.13	0.63	61	39	0.72	0.45
	10-60	4.19	2.96	0.22	0.55	60	13	1.80	1.24
	60-75	0.92	1.14	0.12	1.28	48	7	4.87	1.73
	75-220	1.61	2.45	0.39	4.08	74	12	7.21	3.10
	220-230	0.75	1.97	0.22	1.35	46	9	5.28	2.22
	230-250	0.24	0.63	0.08	0.09	4	24	1.59	1.32

Table 4. The estimated carbon stocks in two sites of the study area

Soil map unit	Soil subgroups	Area extent (ha)	Range of organic C (%)	Range of bulk density (g cm^{-3})	Estimated carbon stocks (ton)
	Site-1 (Central Kalimantan)				
1	Sapric Haplohemists	0.51	44.10-54.24	0.21-0.23	2,833
2	Hemic Haplosaprists	0.78	31.28-54.85	0.22-0.23	3,767
3	Typic Haplosaprists	2.01	37.74-53.05	0.21-0.22	8,607
4	Sapric Haplohemists	1.71	35.39-57.59	0.21-0.22	11,198
	Total	5.01			26,405
	Site-2 (South Kalimantan)				
1	Typic Haplofibrists	2,68	33.75-38.93	0.20-0.09	491
2	Hemic Haplofibrists	1.11	36.62-55.61	0.22-0.08	796
3	Hemic Haplofibrists	1.24	37.79-55.37	0.21-0.08	1,022
4	Typic Haplofibrists	1.69	25.05-47.19	0.17-0.07	1,466
	Total	6.72			3,775

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