Part 1
Peat Science

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Analyses of the Second Layer of Peat Swamp

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Abstract
A purity of silica has been found as a second layer of peat swamp and a few grains of titanium have also found in silica layer as a contaminant. Contaminated several minerals were washed out by a couple of simple rinse with water and resulted silica was applied for X-ray fluorescence analysis to be almost complete silicon (100 w% for silica and 99.88 w% for oxygen). The titanium grain contains 4.13w% of silicon, 54.65w% of titanium and 41.22w% of oxygen. As titanium grain is unable to remove from silica grains unlikely other contaminants and heavier metal than silicon, we can expect to find the higher titanium content in lower layer of silica.

Introduction

Peat swamp has been investigated to convert for the rice paddy in Indonesia to meet for shortage of rice. There are various problems on the conversion of peat land to rice paddy such as lack of weather data through the year, hardness to maintain environmental conditions after the conversion, basic information of composition of peat swamp etc. The preservation of water is the most important problem for the growth of rice plant in the peat swamp, because it is hard to retain the water due to the network composition by fine woods like a filter paper. A large volume of clay or soil is almost impossible to supply to block the water permeation through network of peat land due to geological composition of land, though mad is effective to preserve the water in peat swamp.

Although so many disadvantages were proposed on the peat land fire such as serious influence on the lung function due to aerosol from peat land fire, Prof. T. Kohyama has found the reservation of water around the fire point in peat swamp. This observation gave the useful suggestions to use the sand from second layer of peat swamp on the preservation of water on peat swamp, since the sand tended to become fine particle following to heat treatment around 1,000^{o}C for 1 hour.

The second layer of peat swamp was collected to analyze its contents around Palangka Raya, Central Kalimantan, Indonesia. The second layer of peat swamp brown color around Palangka Raya and became to white following to several rinses by water. Both samples (crude and rinsed) were applied for X-ray diffraction analysis and X-ray fluorescence analysis to detect sand components. The purified sample was treated by heat at 1,000^{o}C for 1 hour to obtain the sand of fine particle size. The fine quartz sand has an advantage for the production of a fused quartz, which is adapted to reform fine quartz sand. The quartz sand has to break its network structure by the addition of Na_2O as shown in Fig. 1 to produce the fused quartz. As quartz is also has several crystalline structure as shown in Scheme 1, we can select proper crystalline structure depend on the application.

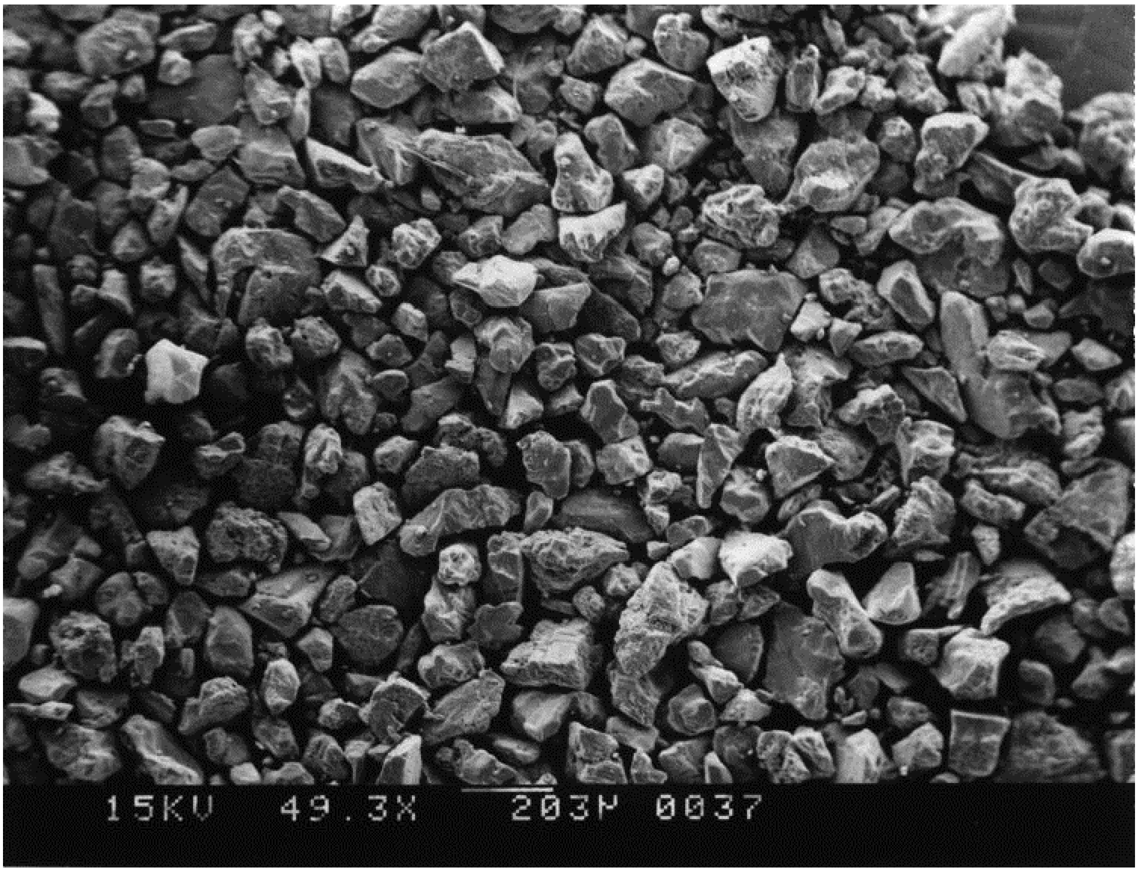
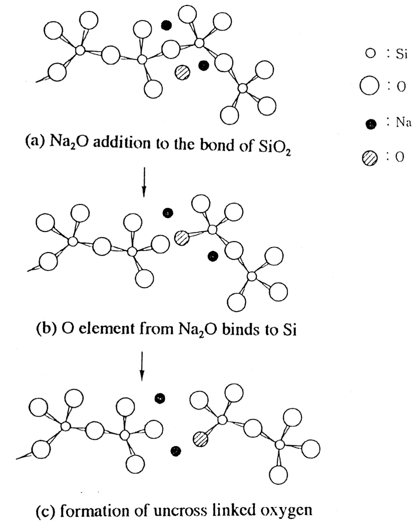


Fig. 1. SEM image of rinsed sand.



Scheme 1. Break of silicon network byNa_2O

Experiments

Sand was collected at Palangka Raya, Central Kalimantan-Indonesia and rinsed with de-ionized water twice followed by drying in air. X-ray fluorescence analysis was achieved to estimate mineral contents. Also the shape of grain was confirmed by scanning electron microscopic (SEM) observation.

Results and Discussion

The almost uniform sizes of sand were shown in Fig. 1 for rinsed sample of SEM picture. There were several unidentified peaks in the X-ray fluorescence spectrum on crude sample in addition to major peak due to SiO_2 and miner one due to TiO_2 as shown in Fig. 2a and 2b. Only one peak, on the other hand, due to SiO_2 was given on the upper layer of the sand. A 100% of purity was given for SiO_2 by X-ray fluorescence analysis (46.74% for silicon and 53.26% for oxygen were found which were identical with those for theoretical values) as shown in Fig. 3. An almost homogeneous size distribution of sand was probably due to sedimentation. So the lower layer is composed of larger size of sands. The homogeneous size distribution would be big advantage for the industrial application together with high purity, if it were allowed to operate under the regulation of environmental conception. Since SiO_2 particles were found to become smaller size following to heat treatment around 1,000^{o}C as shown in Fig. 4, it may apply for the filler against water penetration through SiO_2 layer. Among SiO_2 grains, a different shape of grain was found on SEM picture as shown in Fig. 5. The X-ray fluorescence analysis proved the existence of titanium in the grain as shown in Fig. 6. The purity of titanium oxide was estimated to be more than 88% from oxygen content though there was a slight contaminant.

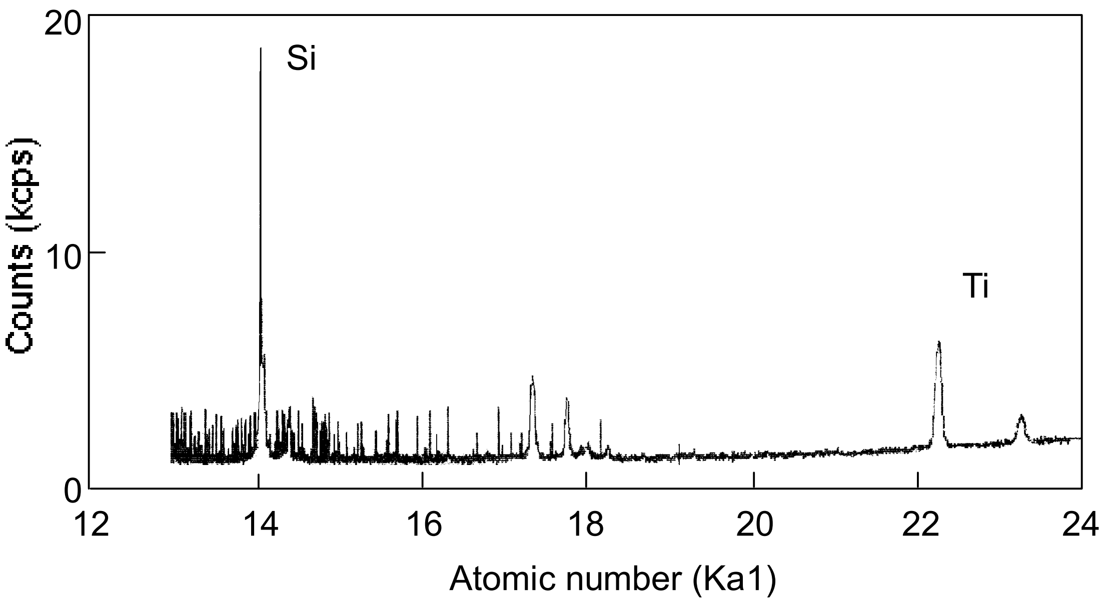


Fig. 2a. X-ray fluorescence spectrum of rinsed sand.

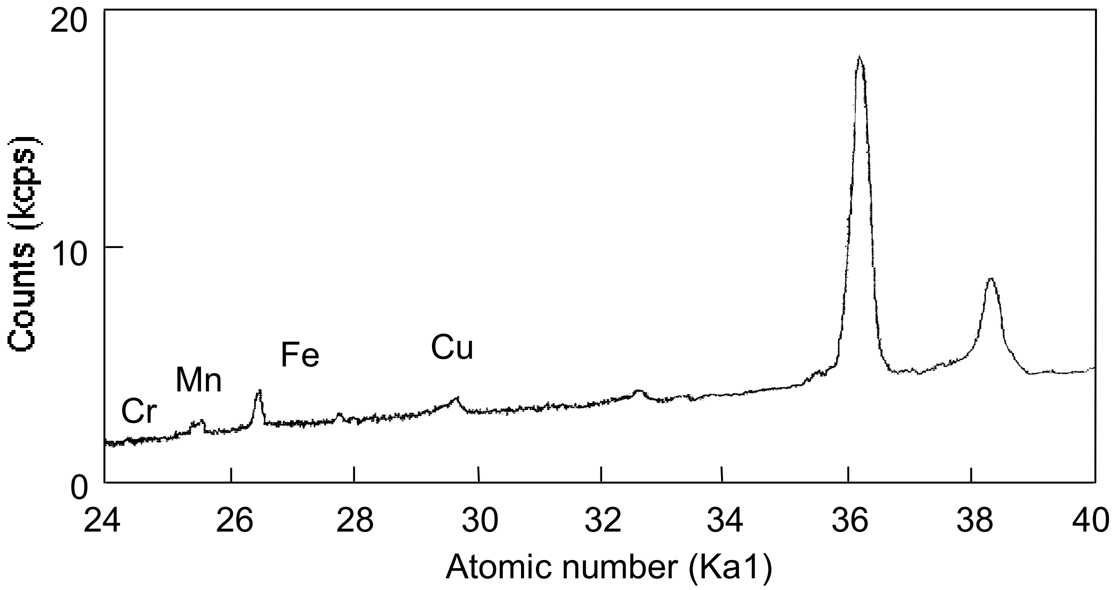


Fig. 2b. X-ray fluorescence spectrum of rinsed sand.

Concentration

	WT %	AT%	"O"%	%S.E.
SiK	46.74	33.33	100.00	0.73
O	53.26	66.67		
	100.00			

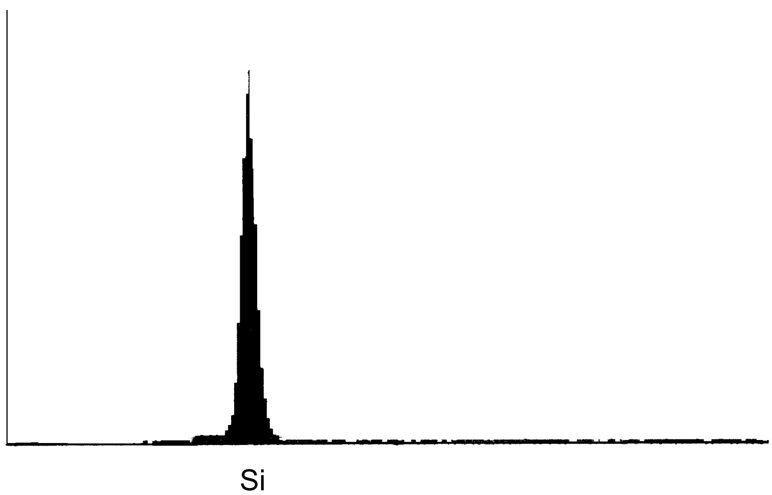


Fig. 3. X-ray fluorescence analysis for rinsed sand.

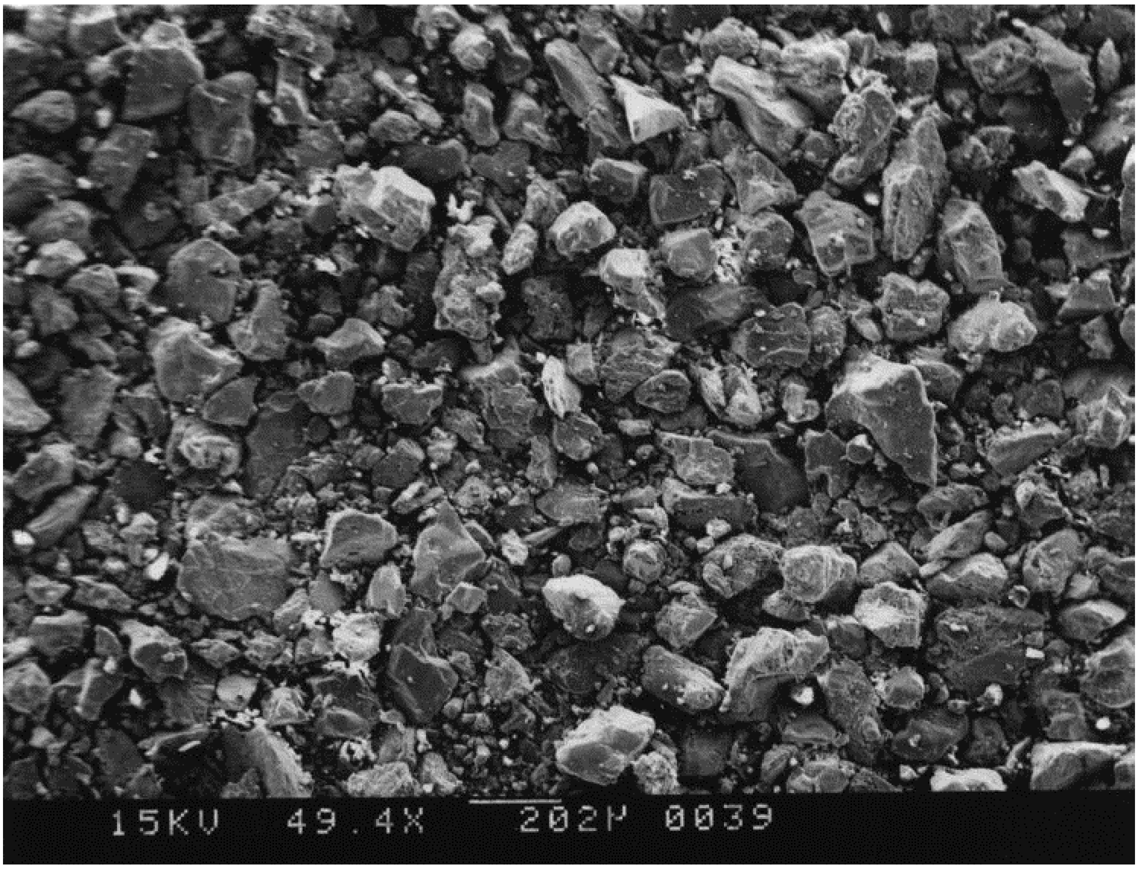


Fig. 4. SEM image of quartz sand heat-treated around 1000˚C.

Since SiO_2 tends to form strong network structure, Na_2O is requested to break the network prior to convert to the quartz of excellent quality as shown Scheme 1. Resulted quartz might be useful as optical fiber, which is the most favorable application of silica sands. The general process to produce quartz optical fiber is melting of highly purified silicon chloride in the presence of oxygen and hydrogen gasses at high temperature. The refractive index of produced quart tends to be relatively high due to contamination of water. However, the quartz from peat swamp SiO_2 would be low refractive index and low cost due to the absence of hydrogen gas on the production of quartz following to the degradation of silicon oxide network by Na_2O.

The composition of peat swamp has to be maintained as former natural figure. However, the conversion of destroyed peat swamp would be permitted to satisfy human demand following reconstruction of basement structure for agricultural and industrial spaces after the recovery of woods area corresponding to hypothetical volume of carbon dioxide respiration before destruction by fire or agricultural operation. Also total volume of silica layer to apply for industrial purpose has to be limited on the viewpoint of reconstruction of nature for living thing.

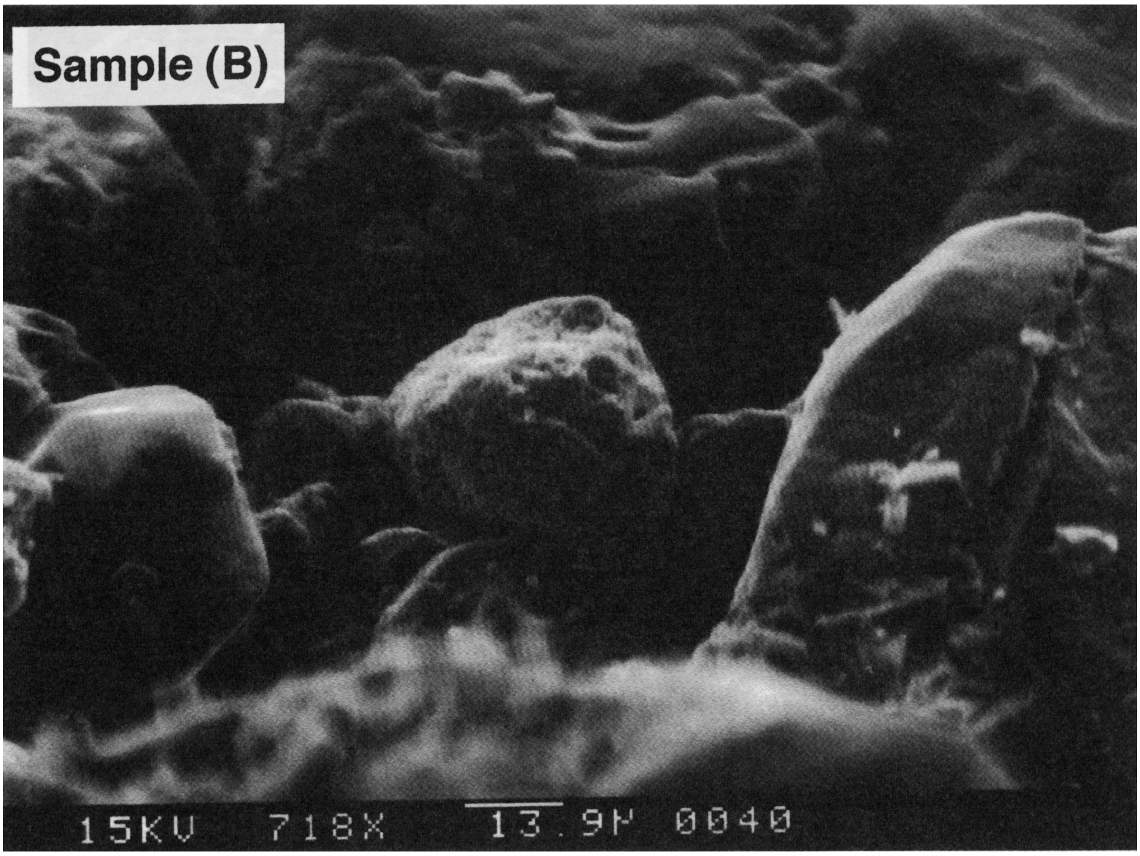


Fig. 5. Expanded SEM image of quartz sand heat treated around 1000˚C.

Concentration

	WT %	AT%	"O"%	%S.E.
SiK	4.13	3.81	8.84	2.34
TiK	54.65	29.53	91.16	0.71
O	41.22	66.67		
	100.00			

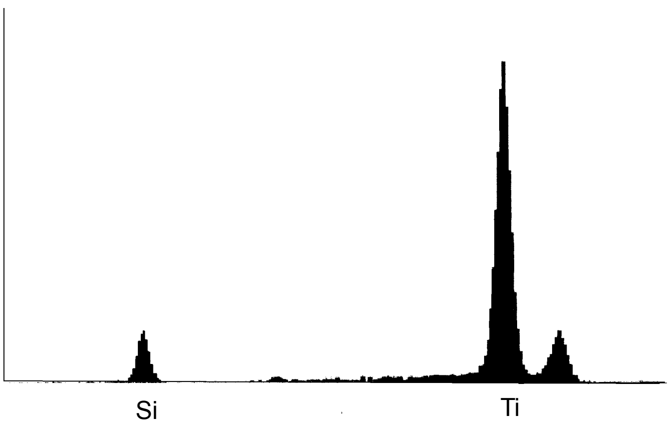


Fig. 6. X-ray fluorescence analysis for heat treated sample.

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The Estimation of Carbon Resource in a Tropical Peatland: A Case Study in Central Kalimantan, Indonesia

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Abstract

Total amount of carbon resource in tropical peatlands is needed to evaluate the importance of the peatland conservation and management. A new method was developed and applied for estimation of carbon resource in a tropical peatland of Central Kalimantan.

The carbon content and distribution in the peat layers measured in different types of peatlands, and the volumetric distribution of peat estimated from the geographic information were used in this new method.

Based on the geographical information from the Land System Map of Regional Physical Planning Programme for Transmigration (RePPProT, 1985), the peatland in Central Kalimantan were classified into five types, basin/domed, terrace, riverine, marginal and coastal peatland.

The average volumetric carbon density (CD_V) of the terrace peatland (71.5 kg m^{-3}) showed significantly greater value ($P < 0.01$) than those of marginal (53.6 kg m^{-3}) and coastal peatland (48.7 kg m^{-3}). The distribution of CD_V in the peat layer of each peatland type has no significant change with depth. For estimation and mapping of peat depth, a multiple linear regression model was used in this study. Five geographic factors, i.e. elevation, slope, distance from a river, distance from Java Sea and distance from a watershed boundary were used in the model.

Key words: carbon resource, Central Kalimantan, multiple regression, peat depth, peatland types, volumetric carbon density

Introduction

Peatlands accumulate carbon over thousands of years and act as carbon (C) sinks. C resource of the peatlands in the world is estimated at 329-528 Pg (=10^{15} g), which account for more than one fifth of the terrestrial C and one third of the whole soil C (Post et al., 1982; Immirzi and Maltby, 1992). In Indonesia, 3.72 Mha of total peat swamp forest had developed (Maltby and Immirzi, 1996), furthermore, 1997/98 forest fire had burnt huge area, not only the surface vegetation but also the underlying peat, of the peat swamp forest in Kalimantan and Sumatra (Page and Rieley 1998). Owing to these drastic land use changes in recent years, an enormous amount of carbon has been released to the atmosphere from tropical peatlands. It is therefore necessary to clarify total amount of C resource in tropical peatlands to evaluate the importance of the peatland conservation and management. Fifteen percent (ca. 70 Pg) of global peatland C exists in tropical peatlands (Immirzi and Maltby, 1992), and from 15.93-19.29 Gt of C resides in Indonesian peatlands, although peat deeper than 6 m is not quantified (Sorensen, 1993). Sorensen (1993) calculated the value of sequestered C by assuming that C content is constant at 53.44% and bulk density of 114.22 kg m^{-3}. Since the great lack of detailed data, particularly in the tropics, on volumetric distribution of peat layers and peat C content characteristics, it is difficult to estimate accurate amount of C resource without any assumption. This work has done in Central Kalimantan to derive a new method that can be easily applied and updated to estimate C resource in a tropical peatland.

Methodology

Most of the estimation models for temperate peatlands are calculated by classifying peatland types and apply their mean values of bulk density, C content and peat depth as representatives (e.g. Gorham, 1992; Botch *et al.*, 1995). However, these models cannot be applied in the tropical peatlands because peat depths vary drastically within a peatland type and sometimes reaches up to 20 m (e.g. Rieley *et al.*, 1992). Hence, we used volumetric carbon density (CD_V), multiplying bulk density (BD) by carbon content (CC), to trace C content characteristics per unit volume, and derived a new model as eq. (1) by classifying peatland types (i) and divided into grid cells horizontally (j) and vertically (k) (Fig. 1).

$$TC = \sum_{i=1}^{n} A_i \sum_{j=1}^{m} d_{ij} \sum_{k=1}^{l} CD_{vijk} \qquad (1)$$

where TC: total amount of carbon resource; A: peatland area; d: peat depth; CD_V: volumetric carbon density; n: number of peatland types patches; m: number of grid cells; l: number of peat layer in depth; i,j,k: natural number. Each parameter is measured or estimated as below. The geographical and the statistical analysis were carried out with Arc View GIS (ESRI) and STATISTICA (StatSoft Inc.), respectively.

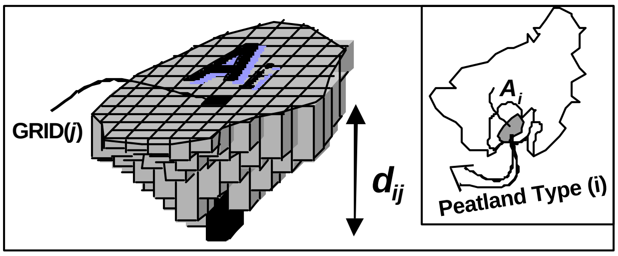

Fig. 1. Model scheme of calculating carbon resource. A: peatland area; d: peat depth

Area and classification of peatland

Based on Land System Map of Regional Physical Planning Programme for Transmigration (RePPProT, 1985), we classified the peatland types of Central Kalimantan into terrace, basin/domed, riverine, and marginal peatland (Table 1; Fig.2a). Area of each peatland type was calculated from this map.

Sampling and analysis of volumetric carbon density

The study sites were located in four different peatland types (Table 2, Fig. 1b). Data of plot PK3 (Neuzil 1997) were added in order to increase number of samples (Table 2, Fig. 1-b). For comparison, some data of Riau (BK5, SK6), Sumatra and Keramat (WK3), West Kalimantan (Neuzil 1997) were also studied (Table 2, Fig. 1a). Since the bases of these peat deposit locate at ca. 0 m a.s.l., we categorized these peatlands as coastal peatlands (Table 1) according to the previous category based on the topographical location (Andriesse 1974; Anderson 1983; Rieley *et al*. 1996).

Table 1. General description, mineralogy and altitude of each peatland type in the tropics.

Peatland type	General description	Mineralogy	Altitude (m)
Riverine	Swampy floodplains mainly within terraces	Resent alluvium (riverine) Peat	0-43
Terrace	Peat-covered sandy terraces	Peat Old alluvium (sand)	5-50
Basin/Domed	Peat basins or domes	Peat	2-10
Marginal	Peat basin margins	Peat Recent alluvium (riverine, estuarine/ marine)	1- 5
Coastal*	Coastal peatlands of the maritime fringe and deltas	Peat Recent alluvium (estuarine/ marine)	1- 5

Note: All the criteria are modified from RePPProT (1985) except for with the asterisked, which are modified from Rieley *et al*. (1996)

Table 2 Characteristics of the study sites and their corresponding peatland types of Central Kalimantan and coastal peatlands in Sumatra and West Kalimantan.

Site	Latitude	Longitude	Elevation (m a.s.l.)	Peatland type	*N*	Peat depth (m) [Min]	[Max]	Mineral layer below peat
Setia Alam Jaya	2°19'S	113°54'E	12*	Terrace	3	[1.8]	[4.1]	Sand†
Marang	2°06'S	113°46'E	18*	Terrace	1	3.0		Sandy clay†
PK3[a]	2°06'S	113°45'E	31*	Terrace	1	6.4		Sandy clay
Petukketimpun	2°08'S	113°53'E	14*	Terrace	1	1.8		Sandy clay†
Tumbangnusa	2°21'S	114°08'E	14*	Basin/Domed	1	3.7		Sandy clay†
Pankoh-B	2°52'S	114°04'E	20*	Basin/Domed	1	5.9		Clay†
Pankoh-M	2°52'S	114°05'E	17*	Marginal	2	[2.4]	[5.3]	Clay†
Tanjung Mas	2°40'S	113°00'E	13*	Marginal	2	[3.8]	[4.1]	Clay†
Lahei	1°56'S	114°11'E	34*	Riverine	9	[1.2]	[7.5]	Sand†
WK3[b]	1°25'S	109°09'E	9	Coastal	1	6.5		Clay
BK5[c]	1°32'S	109°05'E	9	Coastal	1	8.0		Clay
SK6[c]	1°40'S	109°02'E	14	Coastal	1	13.7		Clay

N: number of coring points. *values are interpolated from BAKOSURTANAL (1997); †observed in the field. Compiled from references as follows:[a]Moore *et al*. (1996), Neuzil (1997); [b]Moore *et al*. (1992), Neuzil *et al*. (1993), Neuzil (1997); [c]Neuzil *et al*. (1993), Supardi *et al*. (1993), Neuzil (1997)

Peat samples were collected, divided into 40 cm^3 pieces, oven-dried at 90°C over 24 h and stored for the analysis. Dry bulk density (BD) was determined after measuring peat dry mass. Carbon content (CC) was measured with a CHN elemental analyzer (Elementar Vrio EL). Volumetric C density (CD_V) was calculated by multiplying BD by CC. Since there were a lot of peat layers contain sand or clay near at the bottom of the peat layer and sometimes within the pure peat layer of riverine peatland, we separated these layers and categorized as sandy/clayey layers. ANOVA (Sheffe's test) were used to determine differences between mean values of CD_V among peatland types. Sampling depths were nondimensionalized by dividing the peat thickness of the sampling points in order to trace vertical CD_V difference.

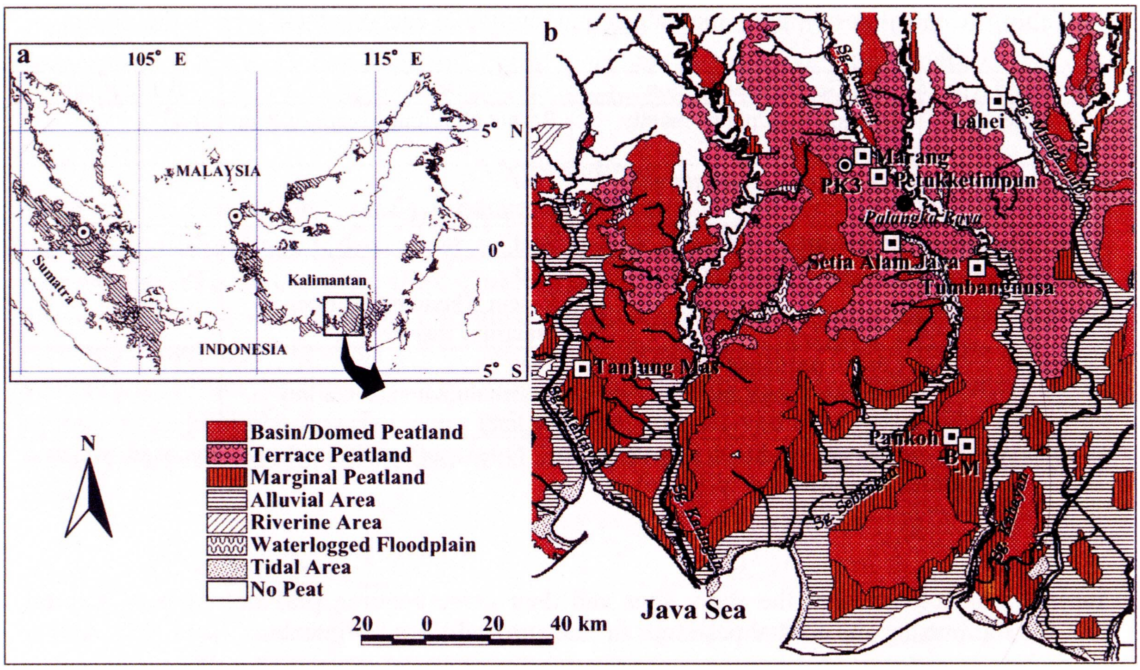

Fig. 2. a: Peatland distribution of Sumatra and Kalimantan. Modified from the Digital Chart of the World (DCW, 1993) and BAKOSURTANAL (1997). Circled points indicate plots of Neuzil (1997). b: Peatland type map of Central Kalimantan. Modified from RePPProT (1985). Squared points indicate study plots. Circled point (PK3) indicates a plot of Neuzil (1997).

Estimation of peat depth

Data on the depths of peat layers in Central Kalimantan were collected by peat boring (Table 2) and compiled from previous reports (Table 3).

50 m grid elevation map were interpolated (inverse distance weighted interpolation, power: 2) from the elevation point from the maps of National Coordination Agency For Surveys And Mapping (BAKOSURTANAL, 1997). Slope and watershed were derived from the elevation map (Fig. 3). Distances from the nearest river and Java Sea were calculated from digitized river line and coastline, respectively, which derived from BAKOSRTANAL (1997). A series of stepwise multiple regression of peat depth against geographic parameters (elevation, slope, distance from river, distance from Java Sea, distance from watershed boundary) was carried out for terrace, marginal, basin/domed peatland and waterlogged floodplain (cf. Fig 2b). Riverine peatland was excluded from the regression model because its distribution largely affected by microtopography.

Table 3. Compiled data used for regression model of estimating peat thickness.

Site name	*N*	Peat depth (m)		References
		[Min]	[Max]	
PK2-6	4	[2.4]	[7.2]	Neuzil (1997), Moor *et al.* (1996)
PR0.5-8	6	[4.0]	[7.0]	Morley (1981)
Setia Alam	78	[2.0]	[10.5]	Rieley *et al.* (1995), Rieley *et al.* (1996), Shephered *et al.* (1997)
KC10-40	66	[0.2]	[3.7]	Euroconcert (1984)

N: number of coring points.

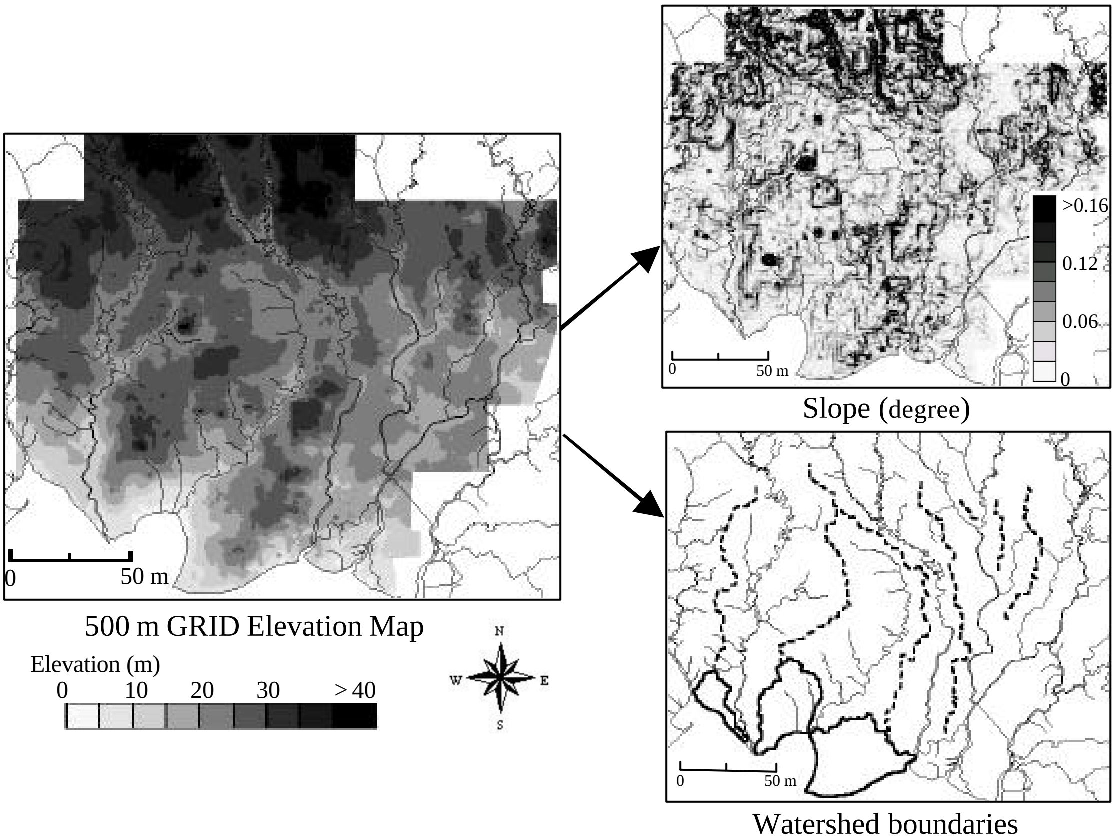

Fig. 3. Elevation map of Central Kalimantan and derived maps of slope and watershed boundaries. The elevation map was interpolated from point data of BAKOSURTANAL (1997).

Results and Discussion

Characteristics of volumetric carbon density

The correlation coefficients (r) of CD_V against nondimensionalized peat depth of riverine, terrace, domed/basin, marginal and coastal peatland are -0.22, -0.10, -0.63, -0.12 and 0.21, respectively. No significant relationships within each peatland type were found between CD_V and nondimensionalized peat depth with the exception within based/domed peatland (Fig. 4), however 2 core data of basin/domed peatland are not enough to clarify significant correlation.

Since CD_V value does not change with depth in most of the cases, the mean CD_V values are calculated from the top to bottom of the peat layers. Input of sand or clay derives significant change (P<0.05) of the peat characteristics, i.e. increase in BD and CD_V; decrease in CC. The mean CD_V value of riverine (64.5 kg m^{-3}) and basin/domed peatland (55.8 kg m^{-3}) is not significantly different (P>0.05) with any other peatland types except for sandy/clayey layer (87.8 kg m^{-3}). The mean CD_V value of the terrace peatland (71.5 kg m^{-3}) shows significantly greater (P<0.01) than those of marginal (53.6 kg m^{-3}) and coastal peatland (48.7 kg m^{-3}), although CC and BD values are not significantly different (P>0.05) among all peatland types (Table 4).

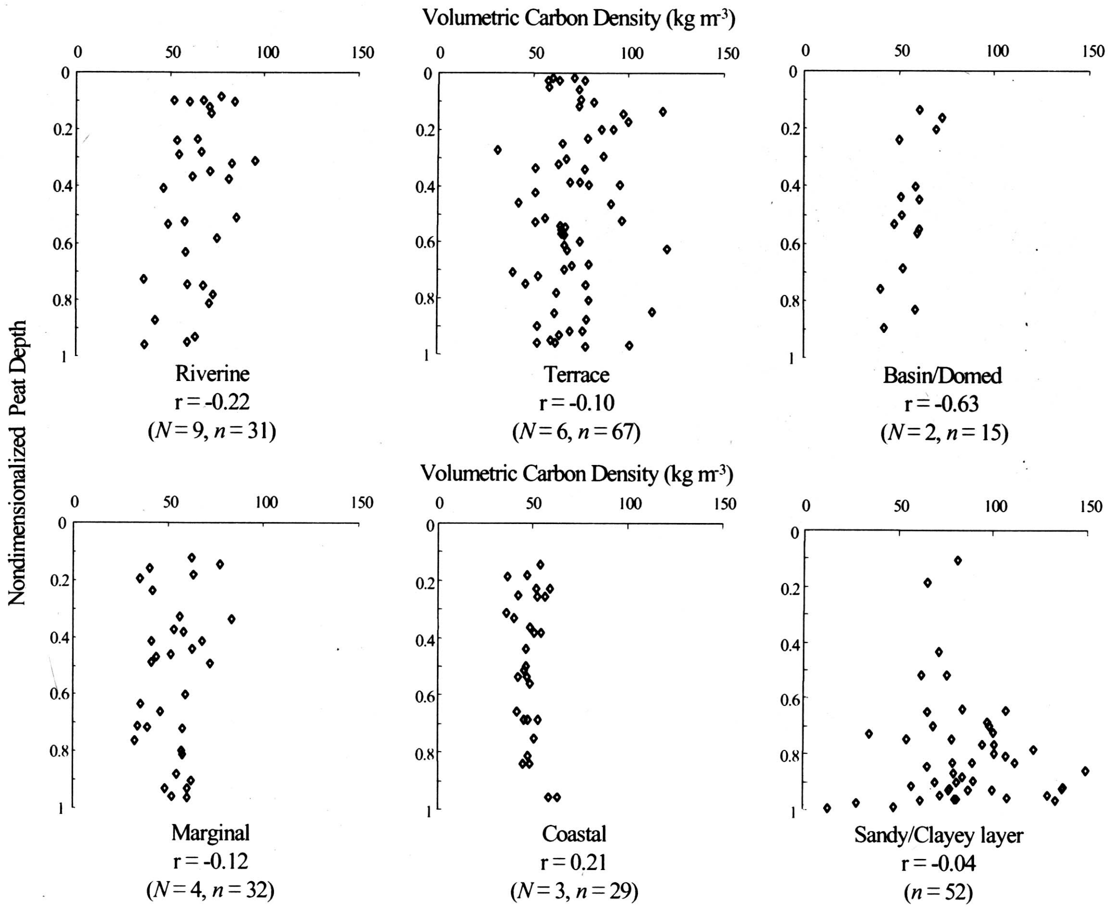

Fig. 4. Variations in volumetric carbon density with normalized peat depth for all peatland types and sandy/clayey layer. Values of coastal peatland and some (n = 9) of basin/domed peatland are adopted from Neuzil (1997). r: correlation coefficient of volumetric carbon density versus normalized peat depth. N: number of coring point; n: number of samples.

Table 4. Peat characteristics of different peatland types in Central Kalimantan and coastal peatland.

Peatland type	n	CC	BD	CD
		% dry weight	kg m^{-2}	
Riverine	31	55.5 ± 4.2[a]	117 ± 27.5[b]	64.5 ± 14.0[de]
Terrace*	67	57.6 ± 4.8[a]	124 ± 31.3[b]	71.5 ± 17.3[d]
Basin/Domed	15	57.0 ± 4.5[a]	98.0 ± 22.3[b]	55.8 ± 8.7[de]
Marginal	32	56.6 ± 3.9[a]	96.0 ± 25.1[b]	53.6 ± 12.5[e]
Coastal†	29	57.3 ± 2.8[a]	84.1 ± 11.5[b]	48.7 ± 6.3[e]
Sandy/Clayey layer	52	35.9 ± 14.7	301 ±179	87.8 ± 30.0

n: number of samples; CC: carbon content; BD: dry bulk density; CD_V: volumetric carbon density. *some data (n = 9) are adapted from Neuzil (1997). †all the data are adapted from Neuzil (1997). Values are the mean ±s.d. Values followed by the same letter are not significantly different at the P<0.05 significance level.

Sieffermann *et al*. (1988) reported the existence of high peats, which is developed on podzolic terraces and formed accumulation in older period (ca. 10000-5000 years BP) than the other peatlands (ca. 6000-2000 years BP) reported previously (e.g. Anderson, 1983). These high peats topographic characteristics coincide with those of the terrace peatland classification, and sampling plots of Marang, PK3, Petukketimpun and a part of Setia Alam Jaya are within the high peats area on the map derived by Sieffermann *et al*. (1988). Hence, the chemical and physical C compaction from the longer decomposition period may attribute to the greater CD_V value of terrace peatland.

Regression models for peat depth estimation

The aspect that the period and the condition of accumulation are different, stepwise regression models were carried out separately for terrace peatland and for the other peatland type (basin/domed, marginal peatland) with waterlogged floodplain. The regression equations are shown as eqs. (2) and (3), respectively:

$$d = 4.60 + 1.02L_R - 0.276\, h + 12.4\, \boldsymbol{F} \tag{2}$$

$$d = -2.48 + 0.547\, L_R + 0.0500\, L_S + 0.0877\, L_W + 11.0\, \boldsymbol{F} \tag{3}$$

where d: peat depth (m); L_R: distance from river (km); L_S: distance from Java Sea (km); L_W: distance from watershed boundary (km); $\boldsymbol{F}$: slope (degree); h: elevation (m a.s.l.); r^2 = 0.538 (F(3,83)=32.27, and P<0.001) for terrace peatland and r^2 =0.747 (F(4,72)=53.13, and P<0.001) for basin/domed, marginal peatland and waterlogged floodplain. From the value of standardized estimate of coefficient, L_R was a best contributor for the prediction of both models (Table 5).

Table 5. Functions for estimating peat thickness of a Central Kalimantan peatland.

Variables	Terrace peatland			Basin/domed, marginal peatland, and water-logged floodplain		
	Coefficient	t-value	Standardized estimate of coefficient	Coefficient	t-value	Standardized estimate of coefficient
Constant	-2.48	-1.87		4.60	7.04	
L_R	0.547	7.14	0.811	1.02	8.71	0.802
L_S	0.0500	6.15	0.425			
L_W	0.0877	1.77	0.210			
h				0.276	-5.54	-0.520
$\boldsymbol{F}$	11.02	1.65	0.103	12.4	2.46	0.212
	r^2 = 0.747			r^2 = 0.538		
	r^2 (adjusted) = 0.733			r^2 (adjusted) = 0.521		
	SE = 1.77			SE = 1.95		
	F(4,72) = 53.1			F(3,83) = 32.3		
	P <0.001			P <0.001		
	N = 77			N = 87		

The map of estimated peat thickness can be derived from the regression models (Fig. 5), although watersheds area which flow into Java Sea is not concerned. Some overestimated parts appeared in the map around high elevated areas between rivers miscounting that the areas are deep peat dome tops. More detailed variables to eliminate those errors and also more distributed surveyed data on peat depth are needed to derive more accurate map of peat thickness distribution.

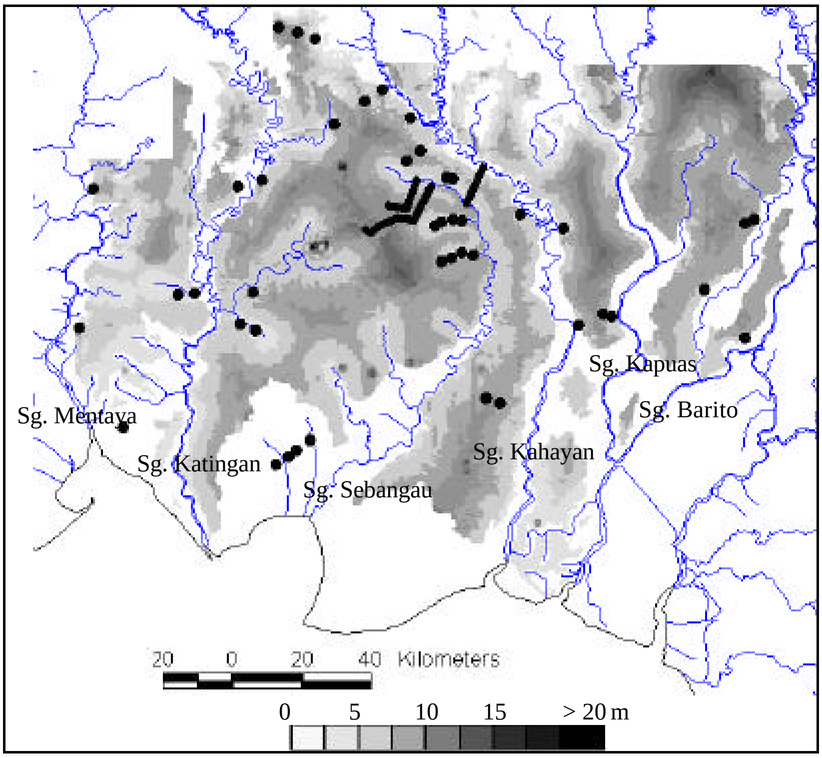

Fig.5 Map of estimated peat thickness. Circled points indicate coring points (*N*).

Estimation model of carbon resource

The results that CD_V does not change with the depth in most of the cases and has its unique value within each peatland type, the estimation model of eq. (1) can be converted to eq. (4).

$$TC = \sum_{i=1}^{n} A_i CD_{Vi} \sum_{j=1}^{m} D_{ij} \quad (4)$$

where TC: total amount of carbon resource; A: peatland area; d: peat depth; CD_V: volumetric carbon density; n: number of peatland types patches; m: number of grid cells; i,j: natural number. Total amount of 5.5 Pg C can be calculated from the eq. (4) between *sg.* (river) Mentaya and *Sg.* Barito, although watersheds area which flow into Java Sea is not quantified. This amount accounts for one tenth of C in total tropical peatlands (Immirzi and Maltby, 1992).

References

Anderson, J. A. R. 1983. The tropical peat swamps of western Malaysia. In: *Mires: Swamp, Bog, Fen and Moor, Ecosystem of the world 4B*. pp. 181-199, Elsevier, Amsterdam

Andriesse, J P. 1974. Tropical lowland peats in South-East Asia. Dep. Agric. Res., R. Trop. Inst., Amsterdam, Commum. 63

BAKOSURTANAL. 1997. Peta rupabumi Indonesia 1: 50000, National Coordination Agency for Surveys And Mapping

Botch, M. S., Kobak, K. I., Vinson, T. S. and Kolchugina, T. P. 1995. Carbon pools and accumulation in peatlands of the former Soviet Union. *Global Biogeochemical Cycles*, **9**(1): 37-46

ESRI. 1993. The Digital Chart of the World for Use with ARC/INFO$^{\cap}$ software from ESRI, Redlands, CA

Euroconsult/ Nedeco. 1984. *Nationwide Study of Coastal and Near-coastal Swampland in Sumatra, Kalimantan and Irian Jaya; Final Report*. P3D, Dit. Jen. Pengairan, Min. of Public Works

Gorham, E. 1991. Northern peatlands: Role in the carbon cycle and probable responses to climatic warning. *Ecological Applications*, **1**(2):182-195

Immirzi, P. and Maltby, E. with Clymo, R. S. 1992. *The Global Status of Peatlands and their Role in Carbon Cycling. Report No.11*, The Wetland Ecosystems Research Group, University of Exeter, U.K.

Maltby, E., Immirzi, C. P. 1996. Introduction: The sustainable utilisation of tropical peatlands. In: *Tropical Lowland Peatlands of Southeast Asia: Proceedings of a Workshop on Integrated Planning and Management of Tropical Lowland Peatlands*. pp. 1-14, IUCN

Moore, T. A. and Hilbert, R. E. 1992. Petrographic and anatomical characteristics of plant material from two peat deposits of Holocene and Miocene age, Kalimantan, Indonesia. *Review of Palaeobotany and Palynology*, **72**:199-227

Moore, T. A., Shearer, J. C. and Miller, S. L. 1996. Fungal origin of oxidised plant material in the Palangkaraya peat deposit, Kalimantan Tengah, Indonesia: Impactions for 'inertinite' formatoin in coal. *International Journal of Coal Geology*, **30**: 1-23

Morley, R. J. 1981. Development and vegetation dynamics of a lowland ombrogenous peat swamp in Kalimantan Tengah, Indonesia. *Journal of Biogeography*, **8**:383-40

Neuzil, S. G., Supardi, Cecil, C. B., Kane, J. S. and Soedjono, K. 1993. Inorganic geochemistry of domed peat in Indonesia and its implication for the origin of mineral matter in coal. In: *Modern and Ancient Coal-Forming Environments*. pp. 23-44, Geological Society of America Special Paper 286

Neuzil, S. G. 1997. Onset and rate of peat and carbon accumulation in four domed ombrogenous peat deposits, Indonesia. In: Rieley, J. O. & Page, S.E. (Eds) *Biodiversity and Sustainability of Tropical Peatlands*. pp. 55-72, Samara Publishing Limited, Cardigan

Page, S. E. and Rieley, J. O. 1998. Executive summary: Field research programme 1996/1997. Report to the South-east Asian Rainforest Research Committee of the Royal Society. Kalimantan Peat Swamp Forest Research Project, Universities of Nottingham, Leicester and Palangka Raya

Post, W. M., Emanuel, W. R., Zinke, P. J. and Stagenberger, A. G. 1982. Soil carbon pools and world life zones. *Nature*, **298**:156-159

RePPProT. 1985. Land systems and land suitability series at 1:250 000 scale. Accompanying Maps of Review of Phase 1B Results, Central Kalimantan. Regional Physical Planning Programme for Transmigration. UK Overseas Development Administration and Directorate Bina Program. Jakarta, Ministry of Transmigration Programme for Transmigration

Rieley, J. O., Sieffermann, G. R. and Page, S. 1992. The origin, development, present status and importance of the lowland peat swamp forests of Borneo. *Suo*, **43**(4,5): 241-244

Rieley, J. O. and Page, S. E. 1995. The ecology and environmental importance of the peatswamp forest in the Sungai Sebangau catchment, Central Kalimantan, Indonesia. Jul.-Sept. 1993 and 1994. A field study programme funded by the Conservation Foundation Earthwatch and Private Subscription.

Rieley, J. O. and Page, S. E. 1996. Biodiversity and sustainacbility of tropical peat swamp forest. A report of field research carried out in Central Kalimantan, Indonesia, Aug.-Sept. 1995.

Rieley, J. O., Ahmad-Shah, A. A., and Brady, M .A. 1996. The extent and nature of tropical peat swamps. In: *Tropical Lowland Peatlands of Southeast Asia: Proceedings of a Workshop on Integrated Planning and Management of Tropical Lowland Peatlands*. pp. 17-53, IUCN

Sorensen, K.W. 1993. Indonesian peat swamp forests and their role as a carbon sink. *Chemosphere*, 27(6): 1065-1082

Shepherd, P. A., Rieley, J. O. and Page, S. E. 1997. The relationship between forest vegetation and peat characteristics in the upper catchment of Sungai Sebangau, Central Kalimantan. In: Rieley, J. O. & Page, S.E. (Eds) *Biodiversity and Sustainability of Tropical Peatland*. pp. 191-210, Samara Publishing Limited

Sieffermann, R. G., Fournier, M., Triutomo, S., Sadelman, M. T. and Semah, A. M. 1988. Velocity of tropical peat accumulation in Central Kalimantan Province, Indonesia (Borneo). In: *Proceedings of the 8th International Peat Congress*. pp. 90-98, Leningrad 1

Supardi, Subekty, A., D. and Neuzil, S. G. 1993. General geology and peat resources of the Siak Kanan and Bengkalis Island peat deposits, Sumatra, Indonesia. In: *Modern and Ancient Coal-Forming Environments*. Geological Society of America Special Paper 286, pp. 45-62.

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Preliminary Study on Geomorphology in the Central Kalimantan Plain with Special Reference to the Tropical Peat Formation

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Abstract

On the basis of newly produced contour map, some aspects of characteristics and evolution and evolution of landforms in the Central Kalimantan Plain was examined particularly in relation to tropical peat development. Widely distributed deep weathering saprolith and residual hills are the definite evidence indicating the long history of this Plain. Depositional surface of kerangas sand is also predominant landforms, in comparison with the relatively narrow area of Holocene alluviation. Peat development appears to have been strongly influenced by the landform evolution of the Plain such as the response of rivers to the sea level change, channel migration, underfitting of rivers probably due to the climatic change. Further geomorphological view is absolutely deeded for understanding tropical peat formation.

Introduction

Development of the thick lowland peat is frequently reported from the tropical zone of the world. It is said that approximately 6.8 Mha peats entirely occupy the lowland up to 60 m or so above sea level in Central Kalimantan . Thick peat cores and/or their geologic cross sections reported so far are obtaind almostly in the region between the present Kahayan River and the Katingan River including the uppermost Sebangau River basin in the Central Kalimantan Plain. However very little is known on the precise distribution of the peat. We have only a rough distribution map of peat by Sieffermann (1988), as shown in Fig. 1. Although considerable attention has been paied to the peat and the forest in Central Kalimantan (eg. Shepherd, *et al*., 1997), but almost nothing is known of the gemorphological evolution. Basic configuration of landforms in Central Kalimantan Plain should be the key issue to discuss not only the formation process, distribution and the other issues of the tropical peat development, but also the hydrological condition. Any topographic maps in the scales of 1:25,000 or 1:50,000 have not yet been published for the Central Kalimantan Plain. Then we produced a contour map based on the elevation data on the map 1:50,000 issued from BAKOSURTANAL (1997) as shown in Fig. 2. Comparing this contour map with the peat distribution so far discussed (Fig. 1), we should discuss some fundamental issues on the geomorphological influence to peat development.

In this preliminary report, we will present some geomorphological interpretation of the Central Kalimantan Plain with reference to (1) its geomorphological characteristics and (2) the sedimentary environment for the peat development. Some noticiable observations in the field will be added.

Landforms and Subsurface Geology

General view

The contour map involves many characteristic aspects of landforms (Fig. 2). It must be above all pointed that the Kalimantan Plain is in low elevation. For example, although the Palangkaraya area is situated inland ca. 120 km from the coast, the elevation is only 15-20 m above sea level or lower than 15 m along the present river level. The area up to the elevation of 100 m asl, more than 200 km inland from the coast, roughly corresponds to the boundary between the plain and the high mountains. However we have landforms such as hills, terraces along the rivers almostly to the area near the present coast, except for the lower Barito River alluvial plain. Katingan River and Sebangau River are at present flowing within the narrow floodplain cutting the terrace landform down to the coast. Only Kapuas River and Barito River have relatively wide present flood plain in the lower reaches up to the height of ca. 10 m above sea level. This alluviation might be caused by that the Barito river system has a wide area of drainage basin in the mountainous region higher than 2000 m above sea level and much amount of sediment supply. Sebangau River basin where the peat is most wildely developing occupies only the area lower than 20 m above sea level.

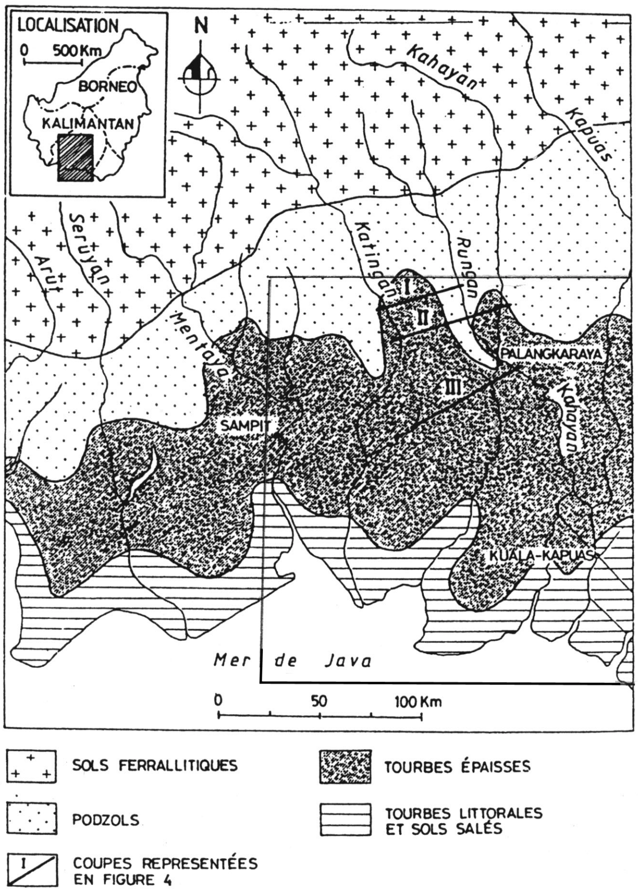

Fig. 1 Distribution of peat and soils in the Central Kalimantan Plain (after Sieffermann, 1988). Box shows the area for Fig. 2.

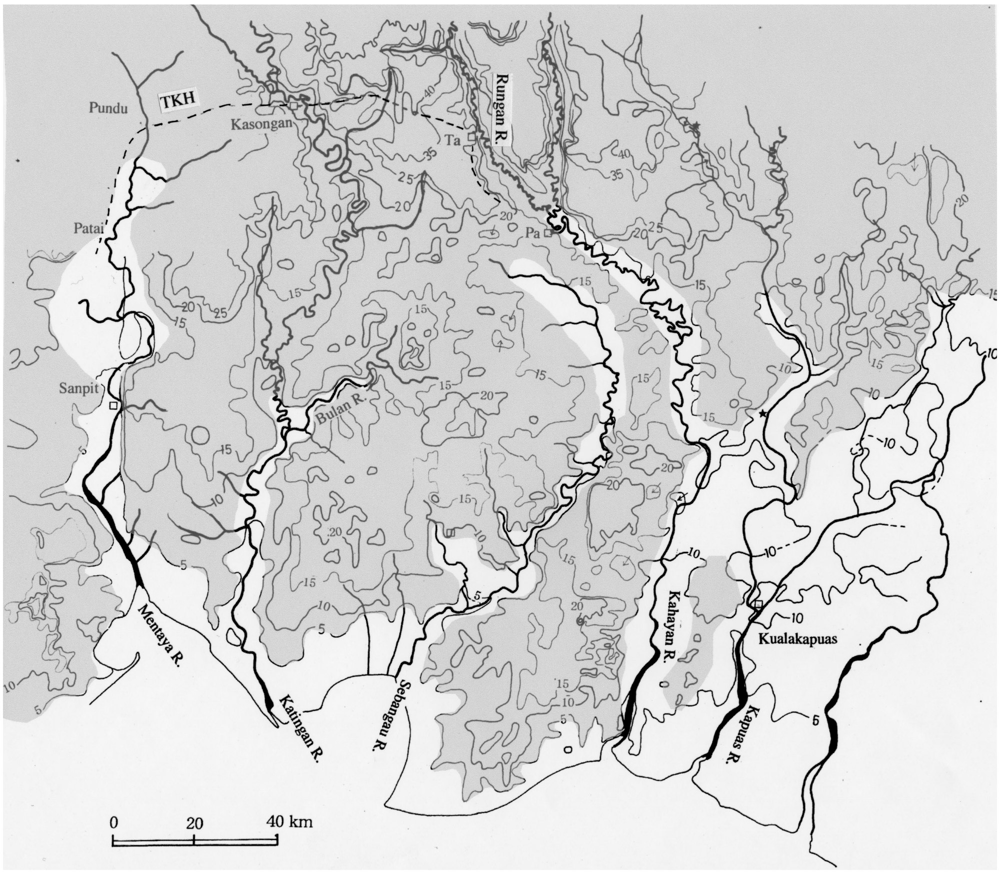

Fig. 2 Topographic (contour) map of the Central Kalimantan Plain.
Contour lines are drawn on the basis of the elevation map of 1:50,000 BAKOSURTANAL (1997). Shadow area indicates the Pleistocene kerangas terraces with residual hills and saprolith weathering.
Pa: Palangkaraya, Ta: Tangkiling, TKH: Trans Kalimantan Highway

Residual hills and weathering

There are residual hills consisting of basement rocks in many places. They are distributed above the plain surface up to ca 100~150 m, as shown for example in Tangkiling Village (cf. Fig.3). Very sharp interface at a weathering front over granite is often typically developed. They are surrounded by the gentle slopes, whose subsurface is deeply weathered to be laterite soil. These landforms and related soils represent a geomorphological sequence of “inselberg and pediment”. At Bukit Batu along the Trans-Kalimantan Highway, to the east of Town Kasongan, similar but smaller landforms and soils including many corestones on the hills and tafoni, weathering pits and grooves are typically developed (Fig.3).

At many localities particularly from Kasongan Town to Sampit City (ex. near Pundu and Patai Villages: see Fig. 2) along the Trans-Kalimantan Highway, we easily notice the deep weathering into the basement rocks which might be basic rocks. We should identify this deep weathering as Saprolite development. The Saprolite horizon must reach the depth more than several tens of meters. It must be noted that similar isolated residual hills are distributed at some localities even near the present coast, judging from the contour configuration representing the isolated small hills.

The submergence of the Sunda shelf seems to contribute such distribution of residual hills. This geomorphological condition appears to provide a fundamental geomorphological environment for the development of coastal peat swamps but there is little evidence of former extensions of the peats to higher levels. These landforms and weathering phenomena must be resulted from the stripping of saprolite to expose fresh rock as bedrock-rooted boulder inselbergs. It is said that these erosional residuals, whether of fresh or saplolite, are the product of a long history.

In the western Kalimantan, Valeton *et al.* (1991) cited the bauxites on the residual hills. It is well known that the formation, evolution and destruction of lateritic formation is closely related to the history of the landform. The time for significant laterite development ensures that they record the environmental changes of weathering and pedogenesis over long periods. It is absolutely certain that the landform of Central Kalimantan Plain is founded by the etchplain with the thick saprolith development.

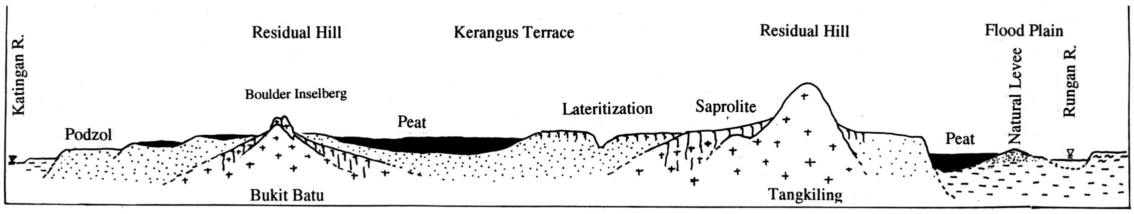

Fig. 3 Schematic cross section of landforms of the Central Kalimantan Plain
This section is according to the landforms between Tangkiling and Kasongan Town vicinity along the Trans Kalimantan Highway

Kerangas Plain

The low-lying Central Kalimantan Plain mainly consists of arkose sand called kerangas, which is podzolized white sand deposits. These characteristic sand deposits have been noted from many tropical humid areas, which is described by Duchaufour (1982) as tropical hydromorphic podzols. Brabant (1987) showed that the correspondence of podzols in Central Kalimantan with the distribution of broad flat interfluves on Quaternary sandy sediments.

It must be first of all stressed that terraced landform with residual hills widely occupies the Central Kalimantan Plain. This Kerangas Plain probably consists of two or three different terraces. As is observed near the Tangkilin Village 2-3 m thick lateritic yellow~red soil is developing on the terrace (Fig.3), while lower terrace surfaces are composed of fresh kerangas sand only with tropical podzol. This sediments contain little-worn gold and angular quartz shards. They appear as podrolized white sand at present, forming terrace-like features that fall more steeply towards the coast line than the gently inclined floodplains. It is noticeable that the kerangas terrace represented by narrow intervals of contour lines 5, 10 and 15 m can be widely followed particularly in the almost whole region between the Kahayan River and the Mentaya River. The dissection of the kerangas surface is more or less taking place. In particular these valleys in the lower reaches, like ex. Bulan River, must have once been deepened in response to the lowering of sea level during the Last Glacial period, and again buried along with the Holocene transgression. The uppermost area of these small dissecting valleys sometimes shows shallow depression. This landform development and related depressional landform in the valley head area seem to be a relevant condition for the peat formation.

How and when has the vast gentle kerangas alluviation taken place? Is the kerangas plain alluvial fan of the Glacial stage in origin? There are large accumulations of alluvial sediments during the Pleistocene also in West Kalimantan. They fall into two groups such as the older terrace deposits of >40 ka and the younger flood plain sediments of < 10.5 ka. (Thorp *et al*., 1990). Thomas (1994) stressed that the sediments may relate to prolonged late Pleistocene low sea levels, combined with drier climate. He suggests that the particular episodes of sedimentation occurred at each of warming peaks on the curve of paleotemperatures for the last glacial cycle. However we need to collect such evidence directly from the Central Kalimantan Plain.

According to Thomas (1994) sudden floods, and rapid deposition might have been the conditions of sedimentation. The late Pleistocene alluviation in Central Kalimantan are almost entirely fluvial in origin and form distinct terraces. Thomas (1994) considers that the rapid deposition and aggradation are clear and large accumulation of kerangas in Kalimantan Plain appears to have been deposited as a result of rapid erosion in small catchment area. It might from this view lead to the conclusion that catchement conditions must have exposed the fragile saplolites to high runoff and severe erosion under an open vegetation cover, although the drainage area of rivers are entirely in an equatorial forest at present.

Holocene alluviation

It is well known that the Java Sea had almost entirely landed to be Sundaland during the Pleistocene low sea level, where extensions of present drainage occurred to have constituted the huge drainage systems. The sea level rise since the Last Glacial Maximum should lead to accumulation in the lower reaches of each river.

Judging from the contour configuration, however, the Holocene transgression seems to have influenced to the development of the Central Kalimantan Plain only in a restricted area. The present meander belt is formed cutting several meters into the kerangas Plain. This implies that the landform development and related subsurface geology in the meander belt are totally different from those of the surrounding kerangas plain. Along such large rivers as the Kahayan River and the Barito River , contour lines of 5 and 10 m intrudes ca. 50~60 km from the river mouth toward the inland. Particularly the flood plain along the Barito River is very widely developed to show a different contour line configuration from those of the other rivers. The Katingan River develops a cuspate delta indicating enough sediment supply. In contrast, the Sebangau River has not prominent sedimentation, but a drowned landform. These areas should be strongly affected by the Holocene transgression.

Abandoned drainage basin and underfitting of river

Along the lower reach of Rungan River, a tributary of Kahayan River, there exists thick peat formation in the flood plain (Fig.3). Rungan dose not have the drainage basin in the high mountains, but restricted almostly within the kerangas plain at maximum 100 m above sea level. However it has comparatively large channel and wide meandering and natural levee or abandoned inter-channel bar. This alluvial lowland of the Rungan River is developed cutting the kerangas Plain. The width of meander belt is almost same as that along the Kahayan River, which occupies the drainage basin in the high mountains up to 1,000 m above sea level.

An important fact for understanding the development of the Rungan River system is that suspended load is not occurring even in the high water condition during the present rainy season. This means that the present the Rungan River is underfitting to the former larger river valley probably during the Last Glacial period. Rungan River during the Last Glacial period probably had much more run-off to produce the larger alluvial plain. The vast area of former flood plain becomes a stagnant water condition during every rainy season, that is the adequate environment for peat development. This must be the condition for the development of thick peat, 3~4 m in thickness.

It must be also noticed that there are some abandoned drainage basins that should have been produced by the large-scale shift of main river channels. The typical example is the Sebangau River basin, which has a drainage area only within the Plain below ca. 15 m above sea level. In comparison with such characteristic drainage area, it has relatively wide alluvial lowland covered with dense vegetation. Such misfitted present Sebangau River implies that river piracy had once occurred around Palangkaraya and thus the upper drainage basin including high mountain region had been cut off from the present Kahayan River System. Vast swampy area of the Bulan River, a tributary of the Katingan River seems to have been influenced by the downcutting and followed burying associated with sea level change through the Last Glacial to Holocene. Thick peat along the Bulan River must depend on this landform evolution.

Some Aspects on the Present Alluviation from Different Areas

Subsurface sediment from Palangkaraya to Kuala Kapuas

We observed the subsurface deposit outcropping along the present river cliff. Although our obsevation is restricted only at several places, we could not any thick peat in this region, but always the fluvial silty deposits. It is particularly significant that subsurface deposits are composed of silt and clay also along the canal excavating the Plain between the Kahayan River and the Kapuas River in this region. Also in the 1Mha area near Dadahup, thick peat is not recognized. According to the distribution map of peat by Sieffermann (Fig. 1), thick ombrogenous peat must be distributed in this region, even though this part of the Kahayan-Barito alluvial plain consists of Holocene fluvial sediments.

Subsurface sediment of the upstream from Palangkaraya

Along the present river channel, the fine sediment can be continuously observed. They consist of the alluvial lowland of the meandering belt. For example, at the site where the village Bawan situated, alluvial deposits of 4 m in thickness are outcropped: upper ca. 3 m is homogeneous light yellowish brown silt~clayey sediments and shows the occurrence of pseydgley process at present. These deposits uncomformablly overlies the dark brown silt~fine sand with laminae or cross bedding containing organic matter. This depositional sequence appears to indicate the general facies of the alluvial lowland in relation to the present meander belt, as far as the upstream region from around Palangkaraya is concerned. The upper silt and clay are supposed to be the deposits due to the recent alluviation, or overbank deposits. On the basis of C-14 date of the organic material, 1920±60 yBP (Beta-131268), the rate of the present alluviation is ca. 2mm/year.

In some places we can observe that these deposits were once cut and then buried by peat. This fact means that the cut off of river channel due to the meandering or the channel shifting within the meander belt is occurring. Peat can be formed only in such a favorite condition within the present meander belt. We should collect such peat at different places in order to obtain the absolute dates and to discuss the variable issues on fluvial geomorphology and present fluvial environment.

Thick peat near Palanglaraya

Only at a site (Berengbengkel) on the Plain near Palangkaraya where the new canal/ditch is excavated, thick woody peat is outcropped. The peat is composed mainly of rainforest trees. The thickness is at least 2.5 m. The base of the peat is not yet outcropped. At this site, several kerangas rip up clasts of 30-50 cm in diameter were contained in the peat formation. These rip up clasts are very significant to discuss the sedimentary environment of the thick peat formation. The rip up clasts must have been eroded by stream water from the nearby river bank while the rainforest tree trunks and the other organic matter had accumulated in the stagnant water condition. Therefore this thick peat is not ombrogernous in origin, but have been developed in or near the (abandoned) river channel. The present fluvial environment of the upper Sebangau River or many abandoned channels during the rainy season appears to represent such a condition. This fluvial environment could be produced by the occurrence of large-scale stream piracy.

Concluding Remarks

On the basis of the topographic map- interpretation and field observation, we can draw some concluding remarks and perspectives as follows:

1. Landforms of the Central Kalimantan Plain are basically consisting of erosional plain with residual hills and saprolith indicating the long-term development. More field description as well as laboratory work are absolutely needed to examine the soil formation under the humid tropical environment.
2. Pleistocene kerangas Plain or geomorphologically terraced surface had developed stripping and burying this erosional surface. Distribution of the ombrogenous peat reported in the previous papers almostly correspond to the kerangas terrace surface. It is not so easy to decide, whether the peat on the kerangas terrace is of ombrogenous or not, judging from the landforms in this regions.
3. Landform evolution since the Last Glacial stage to Holocene must be examined for understanding the development of tropical peat, particularly on the formation process, distribution and type of peat.
4. Present alluviation is restricted to the area along the river channel. C-14 dates of buried tree trunk and fragments often found in this deposits indicate the rate of present alluviation, ca. 2mm/year.

5. The most important and fundamental factor for the peat accumulation in the tropical region is relatively long duration of water stagnation in every year. Occurrence of peat appears to be topographically controlled. They occur in the abandoned meander channel as a plug sediment within the meander belt. On the other hand, most significant thick peat should have been associated with the large-scale channel migration or with shallow depression on the kerangas Plain. The typical example is the uppermost Sebangau River, where the main river had once shifted to the present Kahayan River. Therefore, the present Sebangau River is strongly misfitted to the former large channel and wide meander belt to produce an adequate environment for the peat formation.

6.Considering such geomorphological control of peat formation, the distribution of peat in the Central Kalimantan Plain might have been overestimated in volume. Precise mapping including the views from geomorphological and Quaternary geological development of the Central Kalimantan Plain is still needed.

References

BAKOSURTANAL. 1997. Peta rupabumi Indonesia 1:50,000, National Coordination Agency for Surveys and Mapping.

Brabant, P. 1987. La repartation de podzols a Kalimantan. In *Podzols et Podzolisation*. pp. 13-24, AFES and INRA.

Duchaufour, P. 1982. *Pedology, Pedgenesis and Classification*. Allen, London.

Sieffermann, R. G. 1988. Le systeme des grandes tourbieres equatoriales. *Annal. Geographie*, 544: 642-666.

Thorp, M. B. and Thomas, M. 1990. The timing of allivial sedimentation and floodplain formation in the lowland humid tropics of Ghana, Sierra Leone and Kalimantan. *Geomorhology*, 4: 409-422.

Thorp, M., Thomas, M., Martin, T. and Whalley, W. 1990. Late pleistocene sedimentation and landform development in western Kalimantan (Indonesia, Borneo). *Geologie en Mijnbouw*, 69: 133-150.

Shepherd, P. A., Rieley, J. O. and Page, S. E. 1997. The relationship between forest vegetation and peat characteristics in the upper catchment of Sungai Sebangau, Central Kalimantan. In: *Biodeversity and Sustainability of Tropical Peatland*, pp. 191-210, Samara Pub.,

Thomas, M. 1994. *Geomorphology in the Tropics*. Wiley, 460 pp.

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Chemical Compounds in Gas Emitted from Tropical Peat Soil with Burning with and without Oxygen

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Introduction

The forest fire is connected to the human activities, such as the sifting cultivation, constructing roads, and agricultural development. The big fire gave the serious damage in tropical forest. Especially in 1997, severe forest fire occurred under the dry weather condition (Usup *et al*., 1999). There are few information on the compounds in gas emitted from the burning of tropical peat soils, although the smoke affected the lung of human beings and disturbed the aircraft control (Okazaki *et al*., 1999). The objective of this study is to identify the compounds in gas emitted from the burning of tropical peat soil using double shot pyrolysis (DSPy)-capillary gas chromatography (GC)-mass spectrometry (MS). The analysis of organic compounds in plant, soil organic matter and humic substances has been performed by Curie-point pyrolysis-gas chromatography, although it had the identification problems of lots of peaks (Samukawa *et al*., 1991a, b, 1992). In this report double shot pyrolysis-gas chromatography-mass spectrometry was used.

Materials and Methods

Soil samples were taken from the surface horizon around Mukah and Dalat area of Sarawak: Igan, Dalat, Talau, Mudan, and Mukah (Fig. 1). They were classified into Tropical deep peat soils and Tropical shallow peat soils. The Mukah sample was fractionated by the sieves of 2, 1, 0.5, 0.21, 0.149, 0.105, 0.075 and 0.045 mm in pore size. Carbon and nitrogen content in soil samples were determined by the CN corder (Yanagimoto MT-500). DSPy (Frontier Lab, PY2020D)-capillary GC (Hewlett Packard, HP6890 Series GC System)-MS (Hewlett Packard, HP 5973 Mass Selective Detector) was used for the identification of compounds in gas (Fig. 2). The combination analysis of thermal desorption and pyrolysis of substances have been done (Watanabe, 1996). One mg of soil sample was taken into the sampler. The separation and identification of compounds in gas emitted by the combustion in the pyrolizer was performed by the capillary gas chromatography and mass spectrometry system with Wiley Library (Data Base). Analytical conditions are as follows, pyrolysis temperature: 600°C, carrier gas He: 50 kPa, 1 ml min^{-1}, split vent flow: 100 ml min^{-1}, gas chromatography detector: FID, column: 5% diphenylpolysiloxane, 30 m (0.25 mm in diameter, 0.25 µm film), column temperature: 40°C (3 min) to 320C at 10°C min^{-1}, m/z: 29-500, scan speed: 2 scans s^{-1}.

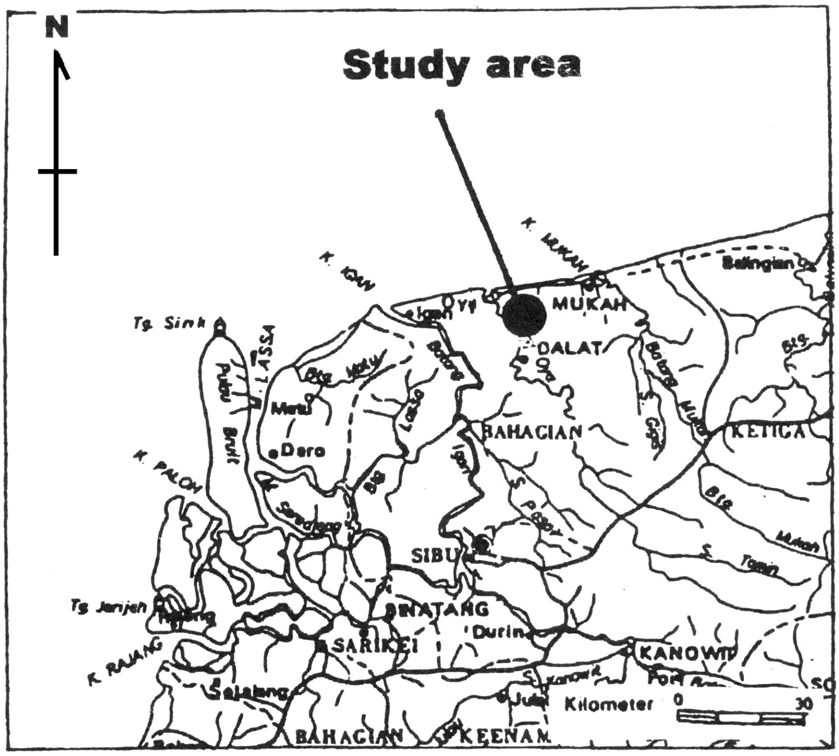

Fig. 1. Study area.

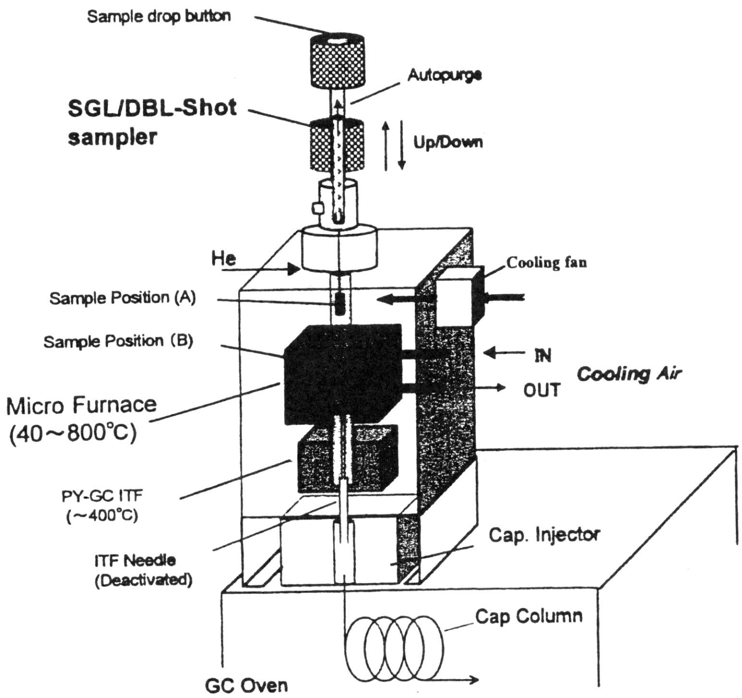

Fig. 2. Double-shot pyrolysis-GC-MS analysis.

Results and Discussion

Carbon and nitrogen content in tropical peat soils

Total carbon and nitrogen content in soil samples shown in Table 1 vary from 383 to 548 g kg^{-1} and 15.8 to 20.8 g kg^{-1}, respectively. The C/N ratios of the samples were in the range of 18.4 to 33.7, with the highest value in Balan. These figures indicated the chemical properties of typical tropical peat soils (Yonebayashi *et al.*, 1991; Yamaguchi *et al.*, 1994). The Mukah sample fractionated by the sieves showed the decreasing tendency of the C/N ratios with the decrease in the particle diameter, suggesting the contribution of high nitrogen content by microorganisms (Table 2).

Table 1. Tropical peat soil samples used.

Location	Classification	Land use	Horizon cm	TC	TN	C/N
Igan	Shallow	Farmer's garden	2-17			
Mudan	Shallow	Farmer's garden	0-15	383	20.8	18.4
Mukah	Deep	Sago plantation	0-10	542	16.4	33.0
Balan	Shallow	Farmer's garden	0-22	533	15.8	33.7
Talau	Deep	Sago experimental station	0-15	548	16.8	32.6

Table 2. Physical fractionation and organic matter content in the Mukah sample.

Diameter, mm	Total carbon, g kg^{-1}	Total nitrogen, g kg^{-1}	C/N
> 2	423.0	20.5	20.6
1-2	509.1	19.8	25.8
0.5-1	256.8	11.4	22.7
0.21-0.5	506.3	21.7	23.4
0.149-0.21	491.4	23.0	21.4
0.105-0.149	469.3	22.8	20.6
0.075-0.105	523.3	26.0	20.1
0.045-0.075	424.5	220.	20.6
0.045-0.075	539.5	26.5	20.3

Compounds in gas emitted from the burning of tropical peat soils

From the gas chromatograms and mass spectrograms of the gas components from Mudan more than 80 compounds were identified as aliphatic and aromatic hydrocarbons, furfurals and organic acids: acetic acid, benzene, pyridine, toluene, furfral, methyl-xylene, stylene, 5-methyl-furfral, phenol, o-cresol, p-cresol, 2-methoxyphenol, catechol 2,3-dihydrobenzofurane, levoglucosan, hydrocarbons with 12 to 32 carbon numbers and so on (Fig. 3). Aliphtic hydrocarbons showed longer retention time than aromatic hydrocarbons. Benzene is one of the cancer-causing subatances for workers (National Astronomic Institute, 1994) (Table 3). Levoglucosan is one of the characteristic substances that emitted from the combustion of the paper or cellulose sample. Fig. 3 also shows the hydrocarbons with 4 to 32 carbon numbers which have none (saturated), one (monoen) and two (dien) double bonding. The chromatograms showed the similar patterns among different soil samples. However, the different concentrations in phenol were obtained, with the highest value in the Mukah sample. The different amounts of compounds emitted from the combustion of tropical peat soil samples were found, based on the temperature and oxygen gas concentrations (Fig. 4).

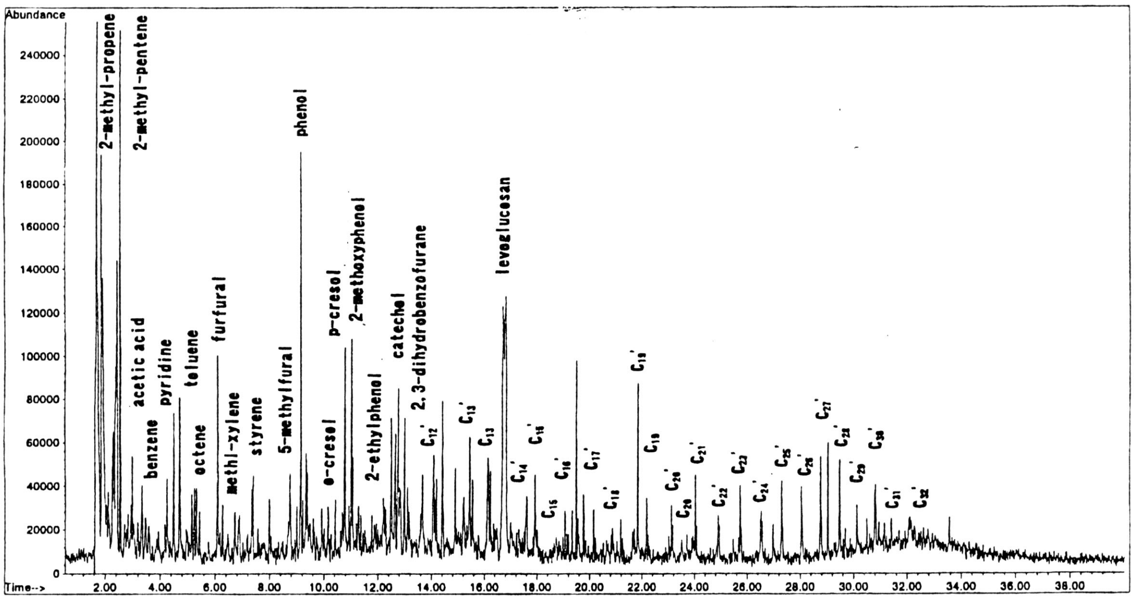

Fig. 3. Gas chromatogram of the gas emitted from the combustion of the Mudan sample.

Table 3. Tentative table of cancer-causing substances for workers (1981). (National Astronomic Institute, 1994)

Substance	
4-aminodiphenyl	$C_6H_5C_6H_4NH_2$
Vinyl chloride*	$CH_2=CHCl$
Asbestos	(chrysotile $Mg_6Si_4O_1$)
2-naphtylamine	$C_{10}H_7NH_2$
4-nitrodiphenyl	$C_6H_5C_6H_4NO_2$
Bis(chloromethyl)ether	$ClCH_2OCH_2Cl$
Benzizine	$H_2NC_6H_4C_6H_4NH_2$
Benzene	C_6H_6
Benzotrichloride	$C_6H_3Cl_3$
Nickel (Refine)**	
Soot, Tar, Pitch and Mineral oil**	
Chromium compounds**	
Arsenic compounds**	

* Vinyl monomer
** All of the cancer-causing compounds were not identified.

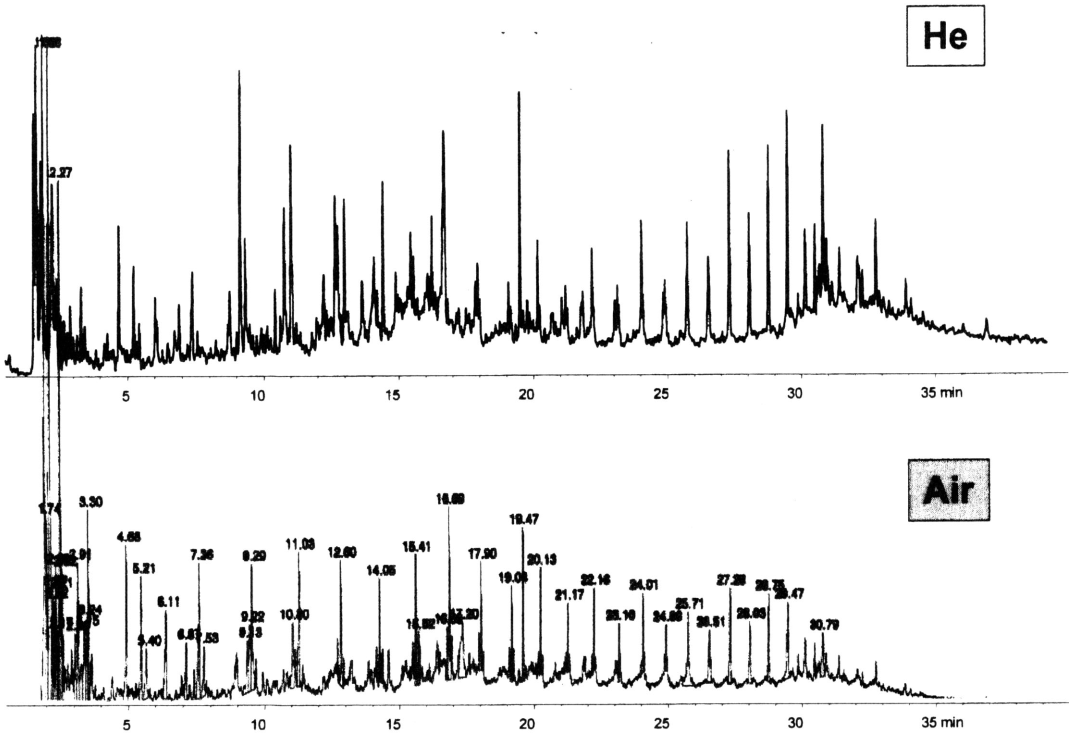

Fig. 4. Comparison of pyrograms in inert and air circumstances at 600°C.

Conclusion

More than 80 compounds emitted from tropical peat soil samples with burning were identified using double-shot pyrolysis-capillary gas chromatography-mass spectrometry.

References

National Astronomic Institute. 1994. *Annual Scientific Book*, Maruzen, Tokyo, p. 586.

Okazaki, M., Watanabe, C., Yoshikawa, M., Yamaguchi, C. and Yoshimura, N. 1999. Chemical compounds in gas emitted from tropical peat with burning with and without oxygen. *Abstracts of International Symposium on Tropical Peatland Management, Ciloto, Indonesia*, JSPS and LIPI, p. 31.

Samukawa, K., Matsuyama, M., Akimori, N. and Komai, Y. 1991a. Chemical characterization of *Chrysanthemum coronarium* roots grown under deficiency of iron nutrient condition by curie-point pyrolysis-gas chromatography-mass spectrometry. *Jpn. J. Soil Sci. Plant Nutr.*, 62: 593-598

Samukawa, K. Akimori, N., Nakata, T. and Komai, Y. 1991b. Chemical characterization of soil organic matter by Curie-point pyrolysis-gas chromatography-mass spectrometry. *Jpn J. Soil Sci. Plant Nutr.*, 62: 599-605

Samukawa, K., Kawaguchi, M. and Komai, Y. 1992. Chemical characterization of soil humic acid by Curie-point pyrolysis-gas chromatography-mass spectrometry. *Jpn. J. Soil Sci. Plant Nutr.*, 63: 10-15

Usup, A., Takahashi, H. and Limin, S.H. 1999. Aspect and mechanism of peat fire in a tropical peatland: A case study in Palangkaraya, Central Kalimantan, 1997.

Abstracts of International Symposium on Tropical Peatland Management, Bogor, Indonesia, JSPS and LIPI, p. 50.

Watanabe, C. 1996. Challenge to the reproducibility of pyrolysis-gas chromatography and its further development. *Bunseki (Analysis)*, 1996(9): 747-752.

Yamaguchi, C., Okazaki, M. and Kaneko, T. 1994. Sago palm growing on tropical peat soil in Sarawak with special reference to copper and zinc. *Sago Palm*, 2: 21-30.

Yonebayashi, K., Okazaki, M., Kyuma, K., Takai, Y., Zahari, A.B., Jiraval, P. and Pisoot, V. 1991. Chemical decomposition of tropical peat. *Tropical Peat: Proceedings of the International Symposium on Tropical Peatland, 6-10 May 1991, Kuching, Sarawak, Malaysia*, Malaysian Agricultural Research Development Institute and Department of Agriculture, Sarawak, pp. 158-168.

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TROPICAL PEATLANDS
Bogor, Indonesia, 22-23 November 1999
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Some Characteristics of Tropical Podzols in Kalimantan

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Abstract

Tropical podzols in Kalimantan have been discussed in term of morphology, geochemistry, and chemical fertility. Tropic al podzols widespread in Kalimantan on flat to gently sloping lowland. Kerangas forest generally covers this soil. The solum is very thick, formed by continuous intensive leaching for long period. The fertility of the soils is characterized by acidity and poor in nutrient elements. The understanding of water cycle in kerangas forest is indispensable to determine both improvement and rehabilitation design.

Introduction

Podzols commonly occur in humid tropic. It differs from those in temperate climate by the great thickness of the solum produced by continuous intensive leaching. Giant podzols (Dames, 1962) or tropical podzols generally apply to name this soil to distinguish it from ordinary podzols. Tropical podzol greatly extends in three provinces of Kalimantan and in Serawak, on flat to gently sloping lowland. Particularities of Kalimantan for the formation of podzols are that geologically, the biggest part of Kalimantan is a cratonic block where volcanism is absent and, climatically, posses a high rainfall since it situated at the equatorial zone. Low fertility status is another characteristic of this soil. The typical land cover of tropical podzols is Kerangas forest, which is easily recognized by its poor in species diversity (Suzuki *et al*., 1999).

The objective of this review is to give the illustration on the podzols in Kalimantan and the general overview of it roles in the ecology of Kalimantan, mainly on water resources.

Methods

A soil profile described in this report was observed at gold mining site at Mandor area in West Kalimantan. Samples have been taken from each horizon of this profile. Fertility Analyses have been carried out following the method elaborated at the Soil Laboratory of R&D Center for Geotechnology - LIPI, summarized below. Mineralogical analyses have been carried out using Philips XRD analyzer with Cu-Kα radiation at two°/min rotation speed. Composition of major elements in mineral fraction of the soil has been also analyzed.

Results

Geographic setting

Kerangas forest, as the marker of tropical podzols in Kalimantan, extends widely, occupies the central part of the islands. This forest formation is mostly widespread at gently sloping lowland plain, situated between dipterocarp forest which covers hilly area and swamp forest which cover flood plains or mangrove which cover tidal plains.

The general pattern of podzols distribution situated at large physiographic transition between coastal area and hilly area of the island. Most of the parent materials of this soil consist of unconsolidated eroded materials, such as colluvium and alluvium deposits. By the presence of relatively high porosity of these parent materials, the mechanism of leaching and soil formation is very intensive that forms a very thick weathering profile.

The Humidity of forest floor is high in most of the years, often inundated either periodically or permanently. Moreover, inundation inhibited organic matter decomposition and provokes plant debris accumulation and form of peat deposit. It is not surprised that kerangas forest soil profile is found beneath several meter peat deposit, mainly at the downstream at the border of coastal area as the consequence of sea level change.

Soil morphology

The typical morphology of soil profile, from the surface toward the depth consists of:

(1) A-0 Horizon: consist of vegetation litter or peat layer.
(2) A-2 Horizons: mixture of organic and mineral fractions.
(3) A-2 or A-E bleached Horizon: white sands and silt.
(4) A-3 or A-B horizon: the transition between A and B-horizon.
(5) B-2 or B-humic or Placic Horizon: loose and structureless black brown sands, silt, and clay when wet and become hard, if dry.
(6) A-3 Horizon: kaolinitic layers or sandy sediments
(7) C-Horizon: parent materials.

A-0 horizon could be presents as very thick peat deposits at inundated area. At undulating area, A-0 is thinner or lack. A1 and A3 normally thinner: less than 10 cm. Whereas A2 and B-2 are generally thick: two to five meters. The total thickness of soil profile in flat area may reach seven-eight meters, whereas at undulating area solum is generally less thick than in the flat area. In the dry undulating area, white sandy A-2 horizon could appear as soil surface. Moreover at severely eroded area, often all A-horizon was completely removed and B-horizon sinks at soil surface.

For most cases its very difficult to make a complete soil profile for description of tropical podzols in Kalimantan due to high water table, beside the solum depth. A detailed soil profile described below is an example of a complete profile which could be observed at a dug pit where the water was pumped for gold mining in Mandor area, west Kalimantan (Table 1).

Table 1. Profile description of podzols at Mandor, West Kalimantan.

Depth, cm	Horizon	Description
0 - 5	A0	Hemic Peat and Roots.
5 - 20	A1	Black (2.5 Y 2/0 to 2/1) sandy peat / peaty sand, medium to coarse sub angular blocky; friable to loose consistency; many medium to fine roots; slightly sticky and not plastic; gradual boundary
20-100	A2 or AE	White (10YR 7/1) quartz sand; loose; clear and wavy boundary
100-300	B-h or B-placic	Black (2,5 YR 2/1) pan inter fingering with yellowish hard iron pan; sandy; structureless; very hard in dry condition and very friable to loose when wet.
<300	Parent material	Sedimentary laminar structured blacky sands and clays.

The described soil profile shows a trace of important erosion. The thickness of A-2 horizon seems very reduced comparing to B-2 which is theoretically the product of accumulation of leached materials from A-horizons.

Soil texture is sand predominant in all depth of the profile. Soil structure and consistency is varied from one horizon to another. In A-0 Horizon, weak to medium sub angular blocky is developed. In A2 the structure is less developed. Loose sands found in A-2 horizon indicating the low proportion of clay. At B-2 horizon, the structure is not developed when wet. After drying B-2, become hard pan, indicating the formation of cementing agent upon drying of clay and complexes metal and organic matter.

Normally high sand fraction content related to high porosity. However, in fact Kerangas Forest soil has a bad drainage property that inundation and flooding usually happen after rainfall. Factors that may reduced porosity could be originated from other smaller sized constituent of soil mass distributed within inter granular pore space of sandy materials. In point of view of soil morphology, B-2 horizon could be suspected as the zone of low porosity in soil profile. High content of clay in C-Horizon could be the important reducer of soil porosity as well.

Geochemistry

Geochemistry of major elements and its distribution within soil profile is listed in Table 2.

Table 2. Chemical composition of major elements (%)

Horizon	SiO_2	Al_2O_3	Fe_2O_3	MnO	TiO_2	P_2O_5	CaO	MgO	Na_2O	K_2O	H_2O	LOI
A1	89.86	1.83	0.04	-	0.62	0.97	0.11	0.02	0.06	0.49	0.79	3.53
A2	91.95	1.70	0.43	0.02	0.75	1.35	0.02	0.02	0.58	0.58	0.19	1.20
B	88.41	3.50	0.93	-	0.98	0.88	0.06	0.01	0.48	0.49	1.51	4.05

SiO_2 is clearly predominant in chemical composition. This indicates that the mineralogical property of the soil is much enriched by quartz. XRD diagram of B-Horizon shows that only Quartz and Kaolinite, which is detected by XRD, analyses. Whereas the quantity of other minerals is very small that could not be detected. In all profiles, the proportion of other elements is less than 10 %. The most of major element concentrations rarely exceed 1%. Iron and Aluminum could be present as oxy-hydroxide minerals such as Goethite and Haematite and Gibbsite, since the content of Crystal-H_2O is significant, mainly at B- Placic Horizon.

The evidence of illuviation on B-horizon appears only for Aluminum, iron and Titanium. Whereas for other elements, the trace of leaching mechanism is not significantly show.

Chemical fertility

Some important chemical fertility parameters are listed in table 3. In general, soil is very acid and poor in nutrient content. The richer part of the soils is at A-0 and B-Placic Horizons and the poorest is A2-horizon. The richness of these horizons seems related to the high value Exchange Capacity (EC). The content of humic substances in both A-0 and B-2 horizons is high (Table 3).

Table 3. Some parameters of chemical soil fertility

Depth,	pH						CEC, meq/100g				EC,	KCl - 1N meq/100g	
cm	H_2O	KCl	C-Org %	N Total %	P_2O_5 mg/100g	K_2O mg/100g	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	meq/100g	Al^{3+}	H^{+}
0-5	3.2	2.9	13.4	0.40	2.71	21.2	1.80	0.59	0.28	0.17	25.56	1.27	2.96
5-20	3.3	3.1	2.0	0.10	1.97	12.2	0.52	0.23	0.17	0.12	5.93	0.04	0.22
20-100	3.8	3.6	0.8	0.04	2.06	10.2	1.54	0.22	0.24	0.11	2.18	0.53	0.22
100-300	5.5	5.2	23.3	0.06	3.74	91.1	1.45	0.09	0.27	1.27	34.82	0.03	0.92
<300	5.0	4.5	0.06	0.01	3.43	18.5	0.51	0.19	0.15	0.05	11.97	1.02	1.62

The contents of all nutrients in the soils are low to very low in whole profile according to FAO criteria (1982). Comparing to chemical composition of the soil mineral fraction (Table 2), the content of available bases within the soils (Table 3) is far lower, even though the content of potassium calcium, magnesium and sodium in the mineral fraction is far from abundant. It seems that most of mineral originated nutrients still presents as non-available form.

Discussion

In spite of few data, the above presentation is pointed at the illustration of general properties of tropical podzols and related ecological problems in Kalimantan. Tropical podzols are known as poor soil. However, even in small quantity, this soil still has nutrient reserves, stored within mineral fraction. The problem is that most of this nutrient present under non-available form for plants. Non-available status of the nutrients due particularly to physico-chemical environment such as acidity. Under natural forest, non-available status of mineral originated nutrients is not an important problem as long as the nutrient cycle is still in a closed cycle. Many scientists believe that in tropical forest, plants uptake their nutrients from decomposed litter.

In disturbed forest such as timber exploited forest, this closed cycle cannot longer be maintained. New nutrient input from mineral soils below organic layer will be needed. One effort could be done to accelerate nutrient availability is to improve physico-chemical environment to be able for nutrient transformation from non-available status into available forms, among others by acidity control. The effort of physico-chemical milieu improvement is more important than fertilizer adding since fertilizer will be useless if the surrounding is unfavorable for nutrient availability.

To introduce milieu improvement within the soils, the understanding of water cycle and soil-plant-water relationship is indispensable, particularly in the forest of Kalimantan where the quantity and quality of water is not easily controllable.

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References

Dames. 1962. *Soil Research in the Economic Development of Sarawak*. FAO report no 1512.

Driessen P. M. and Suhardjo, H. 1974. On the defective grain formation of sawah rice on peat. In: *Proc. ATA 106 Midterm Seminar*. Soil Res. Inst. Bogor.

Hardon, H. J. 1937. Padang soils an example of podsol in tropical lowland. In: *Proc. Kom. Akad. Wet*.

Siefferman, R. G. 1980. Le systeme de grand turbieres equatoriales. Unpubl. Orstom-Paris

Suzuki, E., Kohyama, T., Simbolon, H., Haraguchi, A., Tsuyuzaki, S., Nishimura, T. and Seino, T. 1999. Vegetation of kerangas and peat swamp forests in Lahei, Central Kalimantan. In: *Environmental Conservation and Land Use Management of Wetland in Southeast Asia. Hokkaido University-R&D Center for Biology – LIPI, Ann. Rep. Apr. 1998-Mar. 1999.*