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## ACCUMULATION RATE OF TROPICAL PEAT SOILS UNDER DIFFERENT TYPES OF FOREST

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### SUMMARY

In recent years, conversion of peatland to oil palm plantation has increased in Malaysia due to the higher demand on palm oil. Although it is considered that the land use change from primary forest to agricultural land accelerates the rate of peat decomposition, the strength of impact may vary among the different types of forests. The difference in the rate of peat accumulation may also be related to the decomposability of peat. The objective of the present study is to compare the rate of peat accumulation among the representative types of forests in the Maludam National Park, Sarawak, Malaysia. Soil samples were collected from three forests of Mixed Peat Swamp (MPS), Alan Batu (ABt), and Alan Bunga (ABg), which are located at the edge, middle, and centre parts of peatland in the dome shape. <sup>14</sup>C age, infrared and <sup>13</sup>C nuclear magnetic resonance spectra, and physico-chemical properties were analysed for 5–6 samples from each soil profile, between 100–450 cm depth (MPS), 200–700 cm depth (ABt), and 200–800 cm depth (ABg), respectively. The bottom layer was older in the order of MPS, ABt, and ABg, while the rate of peat soil accumulation based on <sup>14</sup>C age was estimated to be faster in the order of ABg, ABt, and MPS. Spectroscopic analysis suggested the difference in the transition of chemical structure of soil organic matter among the three forest soils, e.g., alkyl components were stored preferentially in the ABg soil while it was reduced with time in the MPS soil.

**Keywords:** accumulation, <sup>14</sup>C dating, tropical peat, vegetation

### INTRODUCTION

Recent studies on the global carbon (C) cycle and climate change have identified the importance of peatland as the sink for the atmospheric CO<sub>2</sub>. Peatland ecosystem has accumulated C because of the slower rate of decomposition compared to net primary production (Frolking *et al.*, 2001). Boreal and tropical peatlands have been estimated to accumulate 455 and 50–70 Pg of C, respectively (Gorham, 1991; Yu *et al.*, 2010). However, the estimation cannot be made with greater precision because of insufficient information on the rate of accumulation of peat deposits (Page *et al.*, 2004). The difference in accumulation rate may also be related to the stability of soil organic matter (SOM), which could be reflected in the rate of peat loss after land-use change for agricultural use. The objective of the present study is to investigate the rate of tropical peat soil accumulation under different types of primary forests.

### MATERIALS AND METHODS

Soil samples were collected from three forests of Mixed Peat Swamp (MPS), Alan Batu (ABt), and Alan Bunga (ABg) in the Maludam National Park, Sarawak, Malaysia in April 2013 (Figure 1). The soil cores were collected by using a peat auger (Eijkelkamp, The Netherlands), with connecting 1-m extensions to the auger head, until reaching mineral substratum (4.5, 7, and 8 m deep in the MPS, ABt, and ABg, respectively). Soil samples with a thickness of 10 cm were collected at intervals of 1.0 or 0.5 m, and those from several cores were combined (100–150 g). Soil samples were covered doubly with aluminum foil and stored immediately in the plastic bags, brought back to the laboratory, and freeze-dried. pH, ash content, and total C and total nitrogen (N) contents were measured using a pH meter (Metrohm 827, Metrohm, Herisau, Switzerland), a thermal gravimetric analyzer (TGA 701, Leco, St. Joseph, MI, USA), and a NC analyzer (TruMac CN, Leco, St. Joseph, MI, USA), respectively. Fourier transform infrared (FT-IR) spectra of the soil samples from upper and lower peat layers of each profile were recorded on a FT-IR spectrometer (FT/IR-4100, JASCO, Tokyo, Japan) using the pellet made from the mixture of soil sample and potassium bromide. The ramp cross polarization/magic angle spinning (CPMAS) <sup>13</sup>C nuclear magnetic resonance

(NMR) spectra of the soil samples were recorded at a  $^{13}\text{C}$  frequency of 176 MHz on an NMR spectrometer (ECA-700, JEOL, Tokyo).

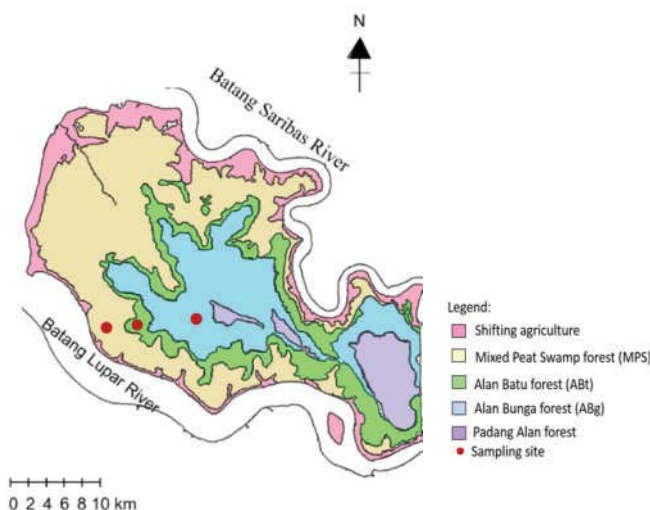


Figure 1: Location of sampling site in Maludam National Park, Sarawak, Malaysia. One red circle covers two sampling sites.

For  $^{14}\text{C}$  dating, the <100 or <200 cm depth layer soils were not used to avoid contamination from living roots. After removal of large plant debris manually, the acid-alkali-acid (AAA) treatment was applied to the soil samples to remove colloidal organic matter contamination from the different layers as follows: The samples soaked in 1 M hydrochloric acid were boiled for 1 hour, and the supernatant was discarded by decantation after it got cold. Similar procedures were repeated using 1 M sodium hydroxide until the supernatant became almost colorless, followed by using 1 M HCl once. The residues were washed with ultrapure water repeatedly and dried up at 80°C in an oven dryer. A sample containing 3 mg of C and 800 mg of CuO were packed in a 9 mm outer diameter quartz tube, evacuated, and sealed at a length of 300 mm. The tube was heated at 850°C for 3–4 h to produce  $\text{CO}_2$ . The  $\text{CO}_2$  generated was purified in a vacuum glass line system and reduced to graphite by reaction with reduced Fe and  $\text{H}_2$  in a vacuum quartz tube at 650°C for 6 h. The  $^{14}\text{C}/^{12}\text{C}$  and  $^{13}\text{C}/^{12}\text{C}$  ratios of the graphite targets were measured using a Tandem accelerator mass spectrometer (Model 4130-AMS, High Voltage Engineering Europa B.V., Amersfoort, the Netherlands). The HOx-II standard (National Institute of Standards and Technology new oxalic acid standard, SRM-4990C) and commercial dehydrated oxalic acid containing no  $^{14}\text{C}$  (Wako, Tokyo, Japan) were used as a reference for the C isotope ratios and for  $^{14}\text{C}$  blank subtraction in the data analysis, respectively. The one standard deviation of the  $^{14}\text{C}$  age of the sample was  $\leq \pm 50$  years. The rate of peat accumulation was estimated by linear regression of  $^{14}\text{C}$  age data and soil depth.

## RESULTS

Throughout this abstract, we show results from one of two profiles for each forest. The pH and ash content of peat soil samples increased at the bottom layers, due to inputs from the below mineral soil layers. Total C content, total N content, and C/N ratio were in the range of 437–592  $\text{g kg}^{-1}$ , 7–17  $\text{g kg}^{-1}$ , and 33–65, respectively (Table 1). Although total C and total N contents in the MPS soils tended to decrease as the soil depth increased, the C/N ratio at 400 and 450 cm depth, 59, was similar to that at 100 cm depth, 60.

The  $^{14}\text{C}$  age was in the range of 2920–5162 years before present (yBP; 0 yBP = AD1950), 1420–4020 yBP, and 928–3277 yBP at the MPS, ABt, and ABg forests respectively. The rate of peat soil accumulation was estimated to be larger in ABg (0.20  $\text{cm year}^{-1}$ ) and ABt (0.17  $\text{cm year}^{-1}$ ) profiles than in MPS (0.07  $\text{cm year}^{-1}$ ).

The IR spectra of the soil samples from an upper (100 or 200 cm depth) and lower (450, 600, or 700 cm depth) layers are shown in Figure 3. Spectral pattern was similar among the samples and major absorptions were observed at around 3410 (O-H), 2850 and 2920 (aliphatic  $\text{CH}_2$  and  $\text{CH}_3$ ), 1710 (carboxylic  $\text{C}=\text{O}$ ), 1620 (aromatic ring  $\text{C}=\text{C}$ /quinone  $\text{C}=\text{O}$ ), 1450–1420 (C-H), and 1030–1066 (alcoholic C-O)  $\text{cm}^{-1}$ , respectively. The absorptions at 2850 and 2920  $\text{cm}^{-1}$  were greater at the upper layer than the lower layer in the MPS soil, while those absorptions were greater in the lower layer soil than in the lower layer soil in the ABg soil profile. The opposite trend was observed in the absorption at 1030–1066  $\text{cm}^{-1}$  in the MPS and ABg soil profiles, respectively.

Table 1: Physico-chemical properties of soil samples used

Study site	GPS point	Sample depth (cm)	pH	Ash (%)	Total C (g kg <sup>-1</sup> )	Total N (g kg <sup>-1</sup> )	C/N ratio
Mixed Peat Swamp (MPS)	1° 25' 53" N 111° 7' 59" E	100	3.5	0.7	578	10	60
		200	3.8	0.4	560	12	45
		300	3.9	0.9	573	11	54
		350	3.9	1.6	566	10	58
		400	4.1	5.7	542	9	59
Alan Batu (ABt)	1° 27' 16" N 111° 9' 4" E	200	3.6	0.9	579	11	51
		300	3.5	0.4	565	14	40
		400	3.6	0.5	575	12	50
		500	3.7	0.7	577	11	53
		600	4.1	1.1	582	10	57
Alan Bunga (ABg)	1° 27' 36" N 111° 9' 27" E	200	3.8	0.5	577	15	40
		300	3.8	0.4	584	14	43
		400	3.9	0.8	585	13	44
		500	4.2	1.3	584	12	47
		600	4.4	1.4	592	11	54
		800	4.3	1.4	583	12	50

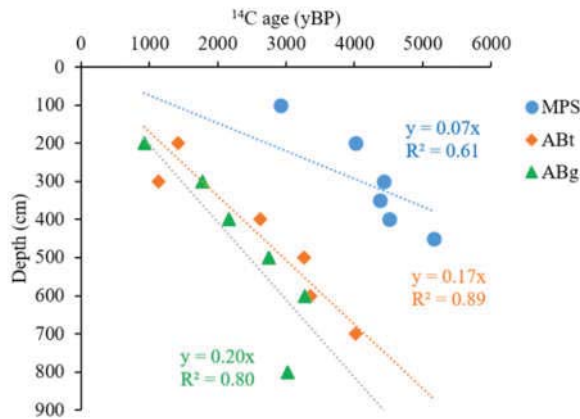


Figure 2: Relationships between soil depth and <sup>14</sup>C age of Mixed Peat Swamp (MPS), Alan Batu (ABt), and Alan Bunga (ABg) forests

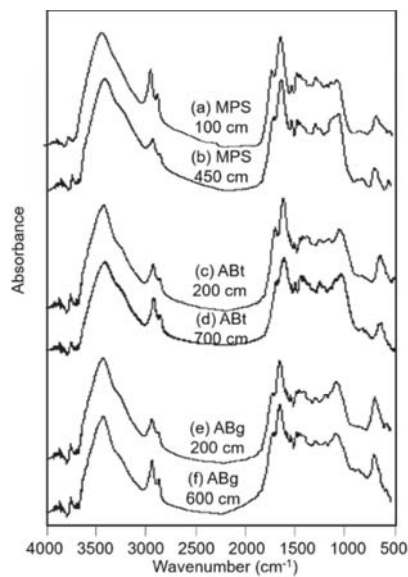


Figure 3: FT-IR spectra of Maludam peat soils from different types of forests. The depth indicates the upper (100 and 200 cm) and lower (450, 600, and 700 cm) layers of each soil profile

## DISCUSSION

The <sup>14</sup>C ages of the bottom layers indicated that the peat accumulation started earlier in the MPS > ABt > ABg, while the thickness of the peat soil was the opposite. These results confirmed that peat accumulation started from the outside of the present peat dome. As the basal dates reported for the lowland peat domes in Sarawak, Malaysia ranged from 1140–6400 yBP (Tie and Kueh, 1979; Staub and Esterle, 1994; Dommain *et al.*, 2011), the history of the Maludam peatland is within this range. Smaller accumulation rate at the MPS site suggests the progression of decomposition/humification. Because the groundwater table was lower in the MPS site, -15 cm, than the ABt (-8 cm) and ABg (-4 cm) sites, more aerobic conditions when each layer was at the surface may have accelerated the SOM decomposition. As the increase in <sup>14</sup>C age with increasing soil depth in the MPS profile was further smaller below 200 cm, when (older than 4,000 yBP) the peat accumulation had not started at the ABt and ABg sites yet, it is contemplated that SOM decomposition was more active or still continue. The rate of peat soil accumulation at the ABg site was closer to that reported for a peatland under continuous saturated condition, 0.25 cm year<sup>-1</sup> (Dommain *et al.*, 2011). In the dome-shape peatland, the inner area is generally more oligotrophic (Funakawa *et al.*, 1996). Such conditions may have accelerated the peat accumulation the ABg forest.

The smaller absorption peaks of aliphatic CH<sub>2</sub> and CH<sub>3</sub> in the IR spectrum of the lower layer than those of upper layer in the MPS soil profile (Figure 3a and b) suggested the loss of lipids and/or other alkyl components with the passage of time. As lipids are less decomposable under anaerobic conditions, this observation agreed to the slower accumulation rate of bulk peat soil in the MPS forest compared to the other forests. Similarity in the IR spectra between the upper and lower layers from the ABt soil profiles is also not contradictory to their almost constant accumulation rates (Figure 2). <sup>13</sup>C NMR results supported these observations.

## CONCLUSION

The <sup>14</sup>C age of the oldest peat soils in the three forest sites indicated the peat dome formation from the edge toward the center of Maludam National Park. The rate of peat soil accumulation was larger in the order of ABg > ABt > MPS. Spectroscopic analysis of the peat soil samples suggested that the transition in the chemical structure with depth or time varies among the three forests, possibly associated with the variation in the accumulation rate.

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