

CHANGE IN THE QUALITY OF DISSOLVED ORGANIC MATTER IN TROPICAL PEAT SOIL UNDER OIL PALM PLANTATION

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SUMMARY

This study investigated the changes in the biogeochemical processes of tropical peat soil that has been reclaimed for oil palm plantation (OPP). We conducted a multi-year monitoring of the quality of dissolved organic matter (DOM) in the underground water of an OPP in Naman, Sarawak, Malaysia, a tropical rainforest climate with unclear wet and dry seasons. The dissolved organic carbon (DOC) concentration and the UV-Visible and fluorescence excitation-emission matrix spectra were measured. EEM was further statistically analyzed using the PARAFAC model. The DOM is shown to be composed of 6 fluorescence components with different behaviour. The quality of DOM varied seasonally and interannually. Some of these changes were explained relating to the seasonal and interannual variations in the underground water level that is brought about in response to seasonal precipitation.

KEY WORDS: Biogeochemical processes, Dissolved Organic Matter Composition, Long Term Monitoring, Oil Palm Plantation, Tropical Peat

INTRODUCTION

Tropical peat has been reclaimed rapidly for large scale plantations in Sarawak, Malaysia, since the 1980s to contribute to the country's overall agriculture production, rural development and economic growth. However, it has been claimed that such large scale reclamation can lead to the rapid decomposition of peat soil, which may lead to the emission of greenhouse gas. In an aid to establish a sustainable development of tropical peat for OPP, it is important to understand the change in the biogeochemical processes of tropical peat soil upon reclamation for OPP.

Dissolved organic matter (DOM) is the most reactive fraction of organic matter in peat soil, the quality of which reflects the source and its diagenetic processes, in other words, the surrounding environment (e.g. Yamashita et al. 2010). Therefore, in order to better understand the changes in the biogeochemical processes of tropical peat under OPP, we conducted a multi-year monitoring of the quality of DOM by using a combination of a measurement of excitation-emission fluorescence matrix (EEM) and its statistical analysis using the parallel factor analysis model (PARAFAC). This technique (EEM-PARAFAC), which is rapid, sensitive, reproducible, and provides high cost performance, enables the quantitative evaluation of the change in the fluorescence component composition. Although only fluorescence components of DOM can be detected, this analysis has contributed significantly

to better understand the origins and dynamics of DOM in natural waters, especially those of dissolved humic substances.

MATERIALS AND METHODS

Study area and water sampling

Naman OPP, which covers 13,145 ha, is located in the southwest region of Sarawak, Malaysia (2° 9'N, 111° 53'E). Sarawak has a humid tropical climate, with an average annual temperature of 26-35°C and annual precipitation of 2000-4000 mm with indistinct wet (Nov-Feb) and dry seasons (Mar-Oct). The elevation of the OPP is 1-17 m above sea level, and the peat depth ranges from 0-16m. Oil palm trees in the studied sites were planted in 2000, 2001-2002, and 2003-2004 at Q1-Q4, Q5-Q8, and Q9-Q12, respectively (Q5 was excluded from this paper since its hydrology of Q5 was very different from the other sites). Groundwater monitoring wells were established in 2008 at a total of 12 locations (Fig. 1). Water samples were collected monthly from the wells for a period October 2008 to June 2011. Sub-samples (30-60 ml) were transported to Kitasato University, Japan, under refrigerated condition for analysis.

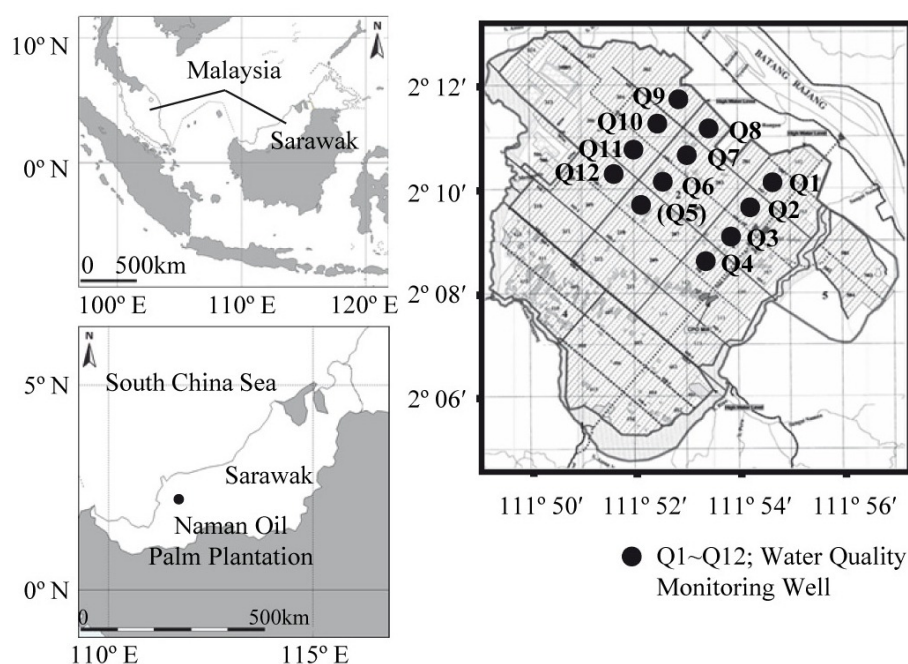


Fig. 1. Map of the studied area and sampling sites

Chemical and spectroscopic analysis of water samples

The water samples were filtered through pre-combusted (450°C for 4h) glass fibre filters (nominal pore size 0.4µm; GB-140, ADVANTEC, JAPAN). The dissolved organic C concentration was measured by a high-temperature catalytic oxidation and IR detection using a Shimadzu TOC-V_{CNH}. The excitation-emission matrices (EEMs) of water samples were measured on a spectrofluorimeter (FluoroMax-4, Horiba Jobin Yvon) equipped with a 150 W xenon lamp as the light source according to Abe et al. (2011). In brief, each EEM was

measured with an excitation wavelength from 240 to 550 nm at increments of 5 nm and the emission signal was scanned in the range of 260 to 600 nm at increments of 2 nm. The inner filter effect was corrected by measuring the UV-Vis absorption spectra of the sample (McKnight et al. 2001; Maie et al. 2006) on a UV-Vis spectrophotometer (UV-1800, Shimadzu). The obtained EEMs were further statistically analyzed using parallel factor analysis (PARAFAC) modeling with the DOMFluor toolbox (Stedmon and Bro 2008) on MATLAB software (ver. 7.7; MathWorks, Inc.) to decompose EEMs into distinct fluorescence components (Stedmon et al. 2003; Stedmon and Bro 2008). The validity of the model was confirmed by split half analysis and Tucker's congruence coefficient (Stedmon and Bro 2008).

RESULTS

Variations in the groundwater level

Average of the groundwater levels of the studied sites was 62 cm, which changed seasonally and positively correlated with monthly precipitation except for Q4. The seasonal change in the groundwater level was obvious in 2008-2009 when a clear seasonality was observed in the precipitation pattern (Fig. 2).

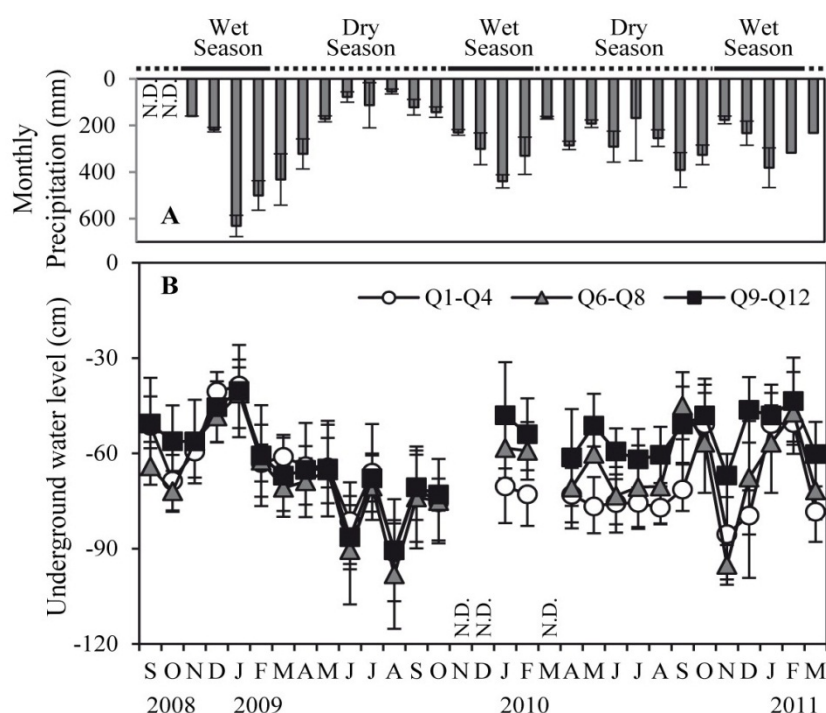


Fig. 2. Variations in the monthly precipitation (A) and underground water level (B). N.D. = no data.

Absorbance at 254 nm (A_{254})

Absorbance at 254nm (A_{254}), which is often used as a proxy for the relative concentration of dissolved humic substance (DHS), showed a seasonal change: it increased in the latter period of the wet season (Jan-Feb) when the groundwater level rose (Fig. 3), which suggested the dissolution of DHS in the groundwater during this period.

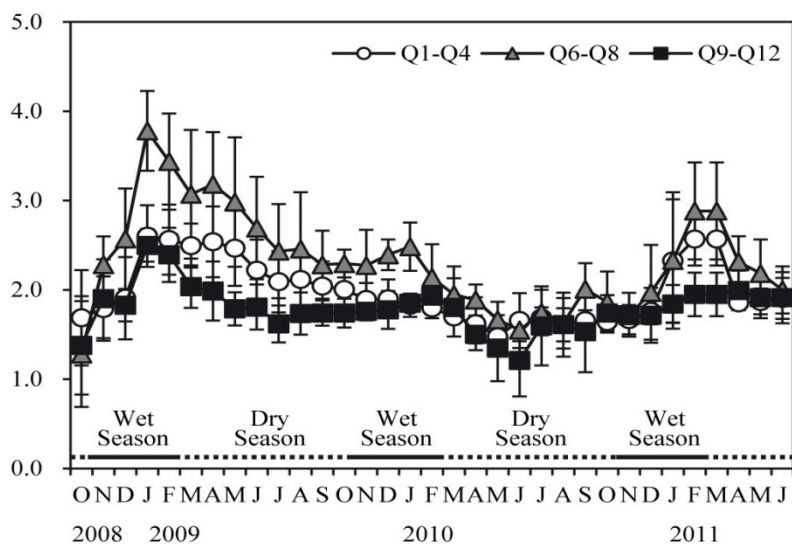


Fig. 3. Variations in the absorbance of water samples at 254nm (A254).

EEM-PARAFAC

EEM are decomposed into 6 fluorescent components (3 terrestrial fulvic acid-type humic-like peaks; 1 microbial fulvic-type humic-like peak; 1 terrestrial humic acid-type humic-like peak; 1 ubiquitous humic-like peak; 1 undefined peak) with different behaviour (Fig. 4). The relative proportion of C1 tended to increase during the dry season except for Q5, while that of C4 behaved oppositely (Fig. 5). Furthermore, the proportion of C1 increased with time, while C4 also behaved oppositely.

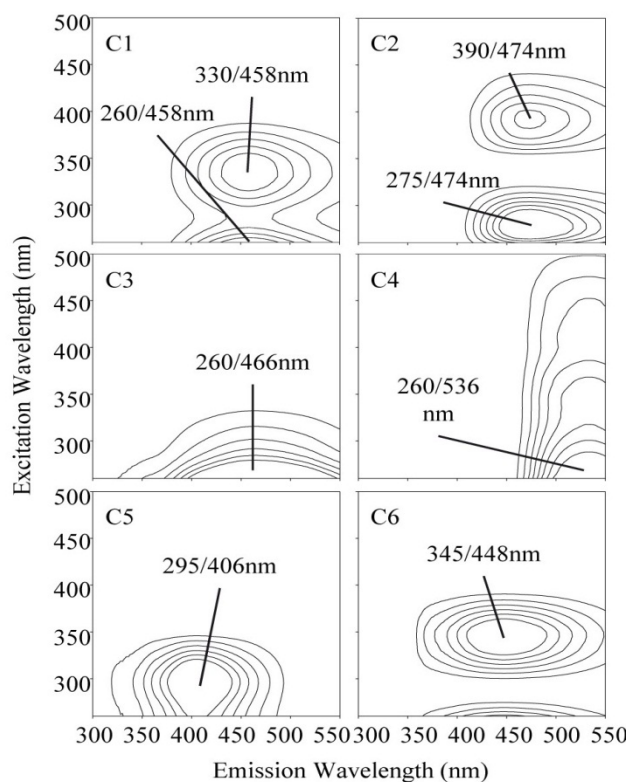


Fig. 4. Six fluorescence components decomposed by EEM-PARAFAC: 3 terrestrial fulvic acid-type humic-like peaks; 1 microbial fulvic-type humic-like peak; 1 terrestrial humic acid-type humic-like peak; 1 ubiquitous humic-like peak; 1 undefined peak were observed.

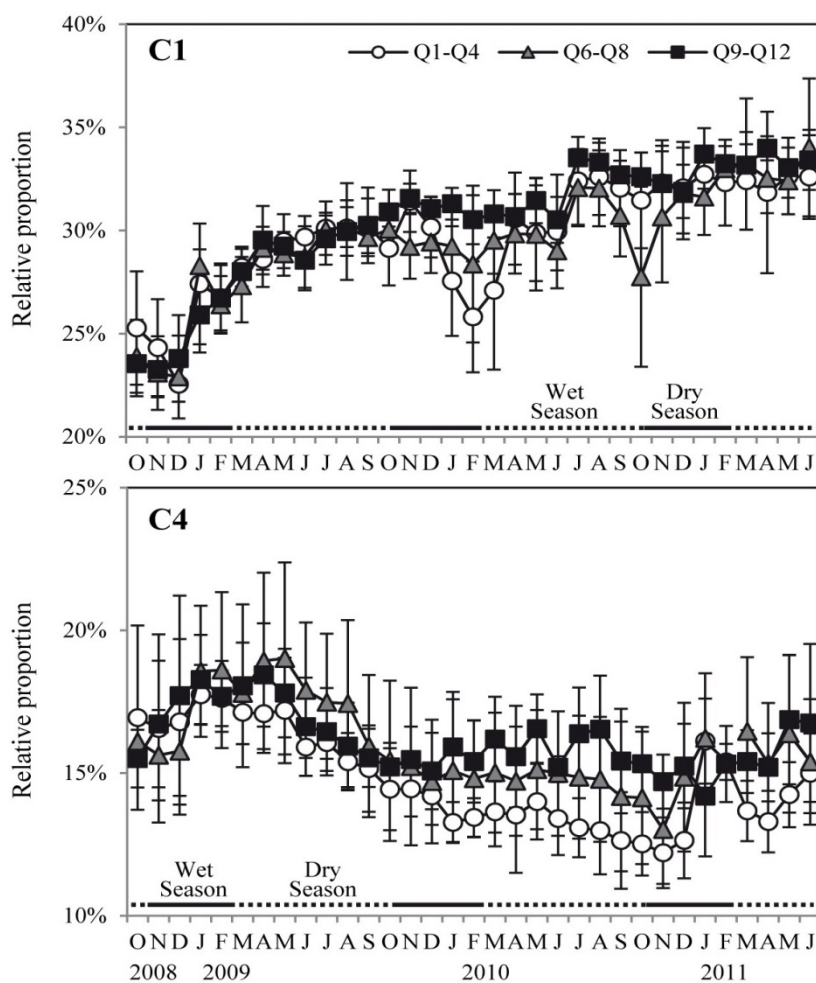


Fig. 5. Variations in the relative proportions of C1 (terrestrial fulvic acid-type humic-like peak) and C3 (terrestrial humic acid-type humic-like peak).

DISCUSSION

Biogeochemical processes of DOM in groundwater

The DOM dynamics in tropical peat soil after conversion to OPP is found to be strongly linked with the change in the groundwater level. Seasonal variations in the quality of DOM is more clearly observed in 2008 when the groundwater level showed a large change in response to clear seasonal change in the precipitation pattern. Peat soil is considered to degrade to form water soluble humic substances (WSHS) when the groundwater level is low during the dry season, because only white-rot fungi can degrade lignins under aerobic conditions. When the groundwater level rises at the end of the wet season, the WSHS was eluted into the ground

water increasing the DHS concentration (Fig. 3). During the dry season, DHS further degrades (oxidize) in groundwater, which is shown by the change in the fluorescence properties: humic acid-type humic-like peak decreases while fulvic acid-type humic-like peak increases during the dry season (Fig. 5). It is noteworthy that the proportion of C1 increased over time, which may suggest that the organic matter in peat soil is being oxidized more under OPP than in the natural state.

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