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IMPACT OF DEFORESTATION ON SOLID AND DISSOLVED ORGANIC MATTER CHARACTERISTICS BENEATH TROPICAL PEAT FORESTS: IMPLICATIONS FOR CARBON RELEASE

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SUMMARY

This study investigated solid and dissolved organic matter elemental, molecular and spectroscopic properties in a pristine and logged over tropical peat forest of Brunei. In the deforested site, dissolved organic carbon (DOC) concentration in the pore water increased significantly compared to the pristine site (from 62.2±2.2 $mg.l^{-1}$ to 79.9±5.5 $mg.l^{-1}$), and its composition was modified: increase of nitrogen content and modification of optic properties (fluorescence index). Logging exploitation of the peat dome also greatly modified organic matter properties and composition: modification of phenolic, as well as sulphur and nitrogen content in the surface soil were observed in the deforested site, indicating an enhanced decomposition following logging exploitation.

KEY WORDS: Tropical peatland, logging, nitrogen, dissolved organic carbon (DOC).

INTRODUCTION

Tropical peatlands are mostly forested. South East Asia contains ~77% of the carbon stored in all tropical peatlands, an amount equal to 11 to 14% of the total pool of carbon stored in all peat (Page et al., 2011). Current deforestation rate for the region is estimated to be 1% (Miettinen et al., 2011). Exploitation of peat forests ranges from selective logging to complete deforestation, drainage and conversion to Acacia and oil palm plantations. Deforestation has both direct and indirect impact on carbon stocks and fluxes in terrestrial ecosystems. In addition to the decrease of above and below ground biomass (Hergoualc'h & Verchot, 2011), the removal of forest canopy modifies local microclimate (interception, solar radiation to soil), and decomposition of left over material from logging often releases a flush of nutrients to the soil (Kreutzweiser et al., 2008). Forested peatlands are even more sensitive to deforestation impact compared to mineral forests (Nieminen, 2004). Investigation of organic matter characteristics, including elemental and molecular analysis can help in assessing processes occurring in peat after exploitation or conversion. Elemental composition and elemental ratios, especially C/N, molecular analysis of sugars and FTIR analysis have been used as proxy and indicators of processes of peat degradation after exploitation in both temperate and tropical peats. Dissolved organic carbon (DOC) composition reflects its origin (vegetation and soil leaching, microbial production) and reveals processes occurring in the peatland. DOC properties (UV absorbance, fluorescence properties) can be used to track processes occurring after change of land use. In tropical peatlands, investigations have been limited to solid peat and only scarce information is available on DOC properties in pristine peatlands and how changes of land use affect them. The objective of the present work is to study solid and dissolved organic matter properties in pristine and logged tropical peatland in Brunei Darussalam in order to: 1/Characterize organic matter properties in pristine tropical peatland, 2/ Determine how deforestation affects organic matter properties, 3/Assess implication of deforestation on carbon cycle in tropical peatlands through organic matter properties.

MATERIALS AND METHODS

Studied sites

The study area is located in the Belait district of Brunei Darussalam (04°N, 114°E). The climate is humid equatorial, with high temperature and high precipitation (average of 2900 $mm.yr^{-1}$). Two peat domes were investigated: one pristine and a recently terminated logging concession that was deforested but not drained.

Sampling procedure

Peat and pore water samples were collected from both domes along radial transects (Figure 1). In the deforested site the transect followed an existing trail. Two sampling locations (Ib, Ic) were added near the centre of the dome, perpendicular to the main transect. These two sampling points are in areas that were logged much earlier than other points along the transect. The sampling sites can be classified as follows regarding the time since logging: (1) The old deforested area (Ib, Ic) which was logged over 20 years ago, (2) The edge of the dome (III, IV, V) which was logged 10-15 years ago and, (3) The centre of the dome (I, II) which was logged less than 3 years ago.

Soil samples

Surface peat (3 replicates) was sampled after litter removal, up to 15 cm depth. Samples were placed in plastic bags, transported to the laboratory, and dried at 60^{o}C. Then, roots were removed. Solid peat analysis included loss on ignition (LOI), soil pH, C, H, N and S analysis, ethanol extractable phenolics and FTIR spectra records.

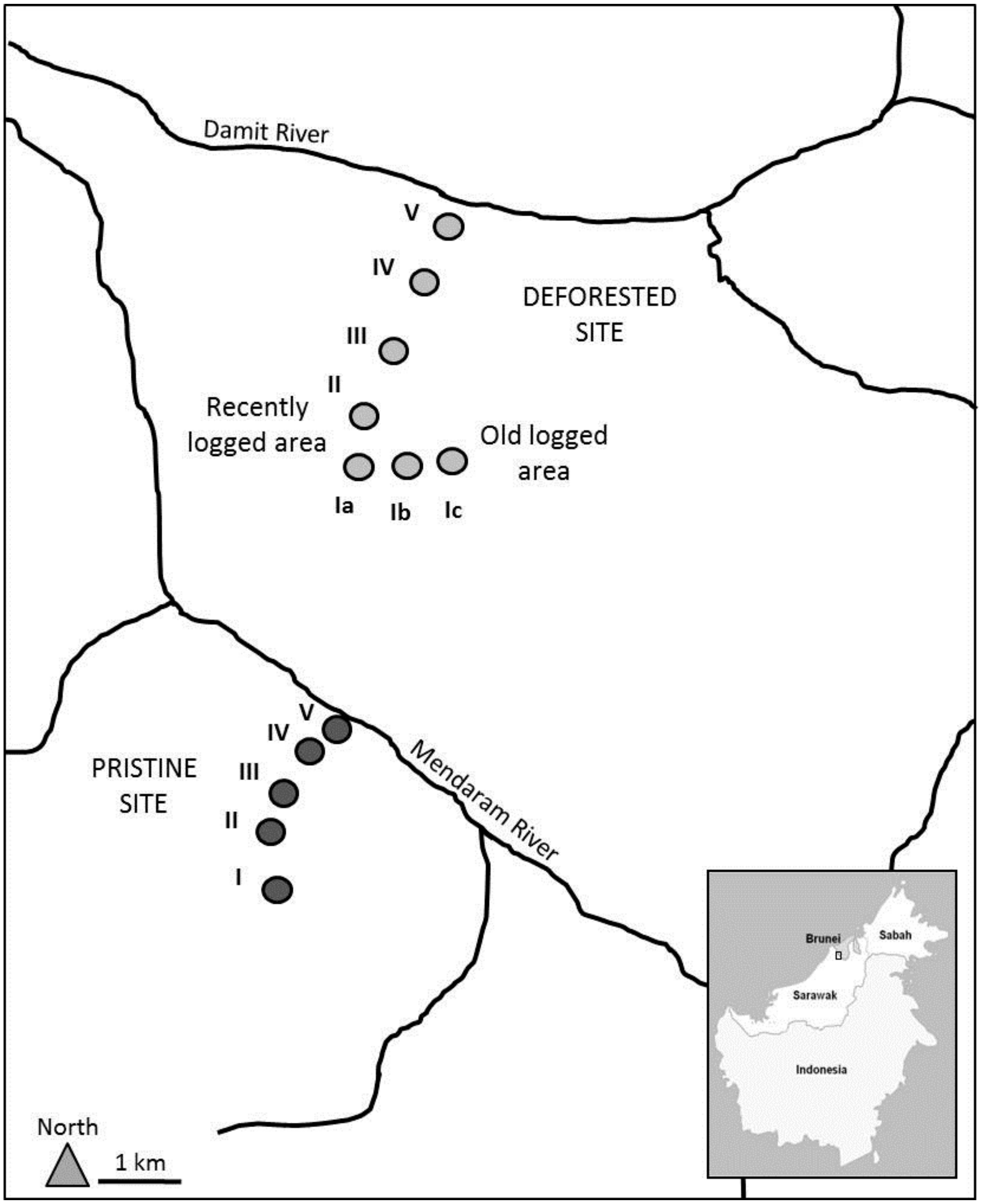

Figure 1: Map of the studied area. Belait area, Brunei Darussalam and location of the sampling points

Pore water samples

Water samples were collected from three sampling locations in the pristine site (III, IV, V) and 4 locations in the deforested site (I, Ic, II, IV, V). At each location on the domes, water was collected from pools on the surface (the water table follows the land surface) and from piezometers inserted at depths of 1 cm, 30cm, 60cm, and 180cm. Conductivity, dissolved oxygen (DO) and pH were measured using flow through cells. Some water was sampled and filtered for major anions and cations, TN and TOC analysis, UV absorbance (200 to 700nm) and fluorescence analysis.

RESULTS AND DISCUSSION

Organic matter characteristics in tropical peat forest

The main organic functions (carboxylates, carbohydrates, phenolics) identified by FTIR analysis were similar to temperate peat originating from sphagnum (Artz et al., 2008) and showed a mixture of lignin, lignocellulose and cellulose.FTIR analysis showed the predominance of lignin associated peaks, typical of the woody origin of the peat (Williams et al., 1998). High DOC concentrations were detected (55 to 95 mg.l^{-1}) in the pore water. The optical properties of DOM in the porewater in the pristine site showed dominance of humic and fulvic acid (fluorescence) and high aromaticity (35%) of the DOC, higher than the values reported for temperate peatland.

Impact of logging: dissolved organic matter (DOM)

Logging activity had an important impact on both DOC quantity and quality in the tropical peat studied. DOC concentration in the porewater increased on average by 30%, from 62.2 to 79.9 mg.l^{-1} (Fig. 2a). The increase of DOC concentrations might reflect enhanced decomposition of the peat. The composition of DOM was modified in the deforested site: increase in the nitrogen content and higher dissolved phenolic concentrations were observed. Lower values of FI were obtained in the centre of the dome, suggesting a more important contribution of molecules originating from peat and litter in relation to enhanced peat decomposition.

Impact of logging activity on peat composition

Analysis of the solid peat samples also indicated higher peat decomposition in the deforested site. FTIR spectra from the deforested site showed more important lignin peaks. In addition, the 1710/1630 ratio, identified as an indicator of peat degradation (Kalbitz et al., 1999), was significantly lower in the deforested site. The nitrogen content also differed in peat from the deforested site, with variations between the sampling sites. Increased nitrogen content was observed in the old logged areas and on the edge of the dome (Figure 2b). Higher nitrogen content has been used as indicator of peat degradation (Malmer & Holm, 1984; Anshari et al., 2010). During peat evolution, carbon is preferentially lost through aerobic decomposition of easily disintegrating carbohydrates. This results in an enrichment of nitrogen in the peat. In the recently logged area, N content of solid organic matter was not modified. In these areas, higher phenolic content was measured in the peat. Phenolic compounds, present in numerous plant species could have been added to the peat surface as a results of decomposition of slash. These compounds are known to inhibit peat decomposition (Freeman et al., 2004). This could explain the fact that in the recently logged areas, no significant modification of the nitrogen content of the soil was observed. We hypothesize that logging exploitation of the peat forest has induced higher peat decomposition. Although, this effect is time dependent. Just after logging, the release of phenolic compounds has an inhibitory effect, which disappeared after degradation and leaching of the phenolic compounds.

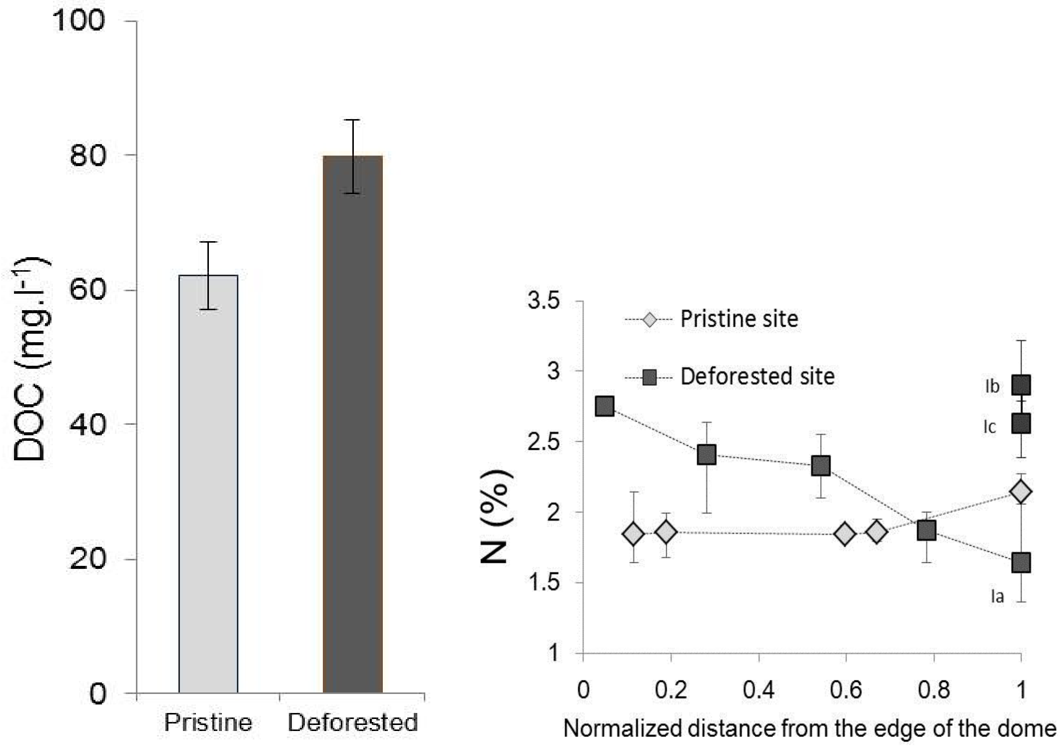

Figure 2: (a) Average DOC concentrations in the pore water of the pristine and deforested site. n=30 for each sites (b) Nitrogen (% of dry mass) content of surface soil of the two studied soil Average, min and max of the 3 replicates.

Implications for carbon fluxes

In tropical peatland, forest logging activity often requires drainage of the peat for log export from the forest and is subsequently expected to induce a large release of CO_2 to the atmosphere due to the lowering of the water table (Couwenberg et al., 2010; Page et al., 2011). This study is providing insight to the hypothesis that even without drainage and lowering of the water table, a large amount of decomposition of the peat has occurred. In fact, logging activity can induce important changes to the microclimate of the peat, by modification of the water budget, reduction of the atmospheric moisture interception and increase of solar radiation. This could have led to a relative drying of the surface and increase of temperature, thus enhancing microbial decomposition of the peat.

CONCLUSIONS

This study provides new data on solid and dissolved organic matter properties in pristine and selectively logged tropical peat forests. DOC concentration increased significantly in the logged dome, suggesting enhanced peat decomposition , even with no engineered lowering of the water table. This was confirmed by the important modification of organic matter properties observed in the logged dome compared to the pristine one, modification of increased lignin, phenolic nitrogen and sulphur contents.

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