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CHARACTERIZATION OF ORGANIC CARBON COMPOUNDS OF TROPICAL PEAT FROM VARIOUS LAND MANAGEMENT TYPES

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SUMMARY

The carbon chemistry largely determines the decomposability of organic substrate. The advanced knowledge of tropical peat organic carbon chemistry (OCC) improves understanding of carbon dynamics, which is needed for sustainable management of these ecosystems. Yet, tropical peat OCC is a highly understudied subject. To study tropical peat OCC we gathered samples from undrained peat swamp forest and three other land uses altered 20–30 years prior to the study, which together form a continuum of increasing land-use intensity. From studied peats collected from in Central-Kalimantan, Indonesia, the OCC, i.e. the hemicellulosic carbohydrate and uronic acid compositions and concentrations of extractives, cellulose, acid-soluble lignin and acid-insoluble residue were determined. With this study we aim to answer the following questions: (i) Does land-use change affect tropical peat OCC? (ii) How does land-use change affect OCC? (iii) What kind of implications could changes in OCC cause to carbon dynamics at various land use types?

Keywords*: tropical peat, land-use, decomposability, carbohydrates, polymers*

INTRODUCTION

Decomposability of organic substrate largely depends on its carbon chemistry (Berg, 2000; Zhang *et al.*, 2008; Sanaullah *et al.*, 2010; Strakova *et al.*, 2011). This relationship particularly holds true for tropical peatlands, which are formed of deep organic matter depositions. Large-scale land reclamation including drainage and deforestation has taken place in Southeast Asia with accelerating extent (Murdiarso *et al.*, 2010; Miettinen *et al.*, 2016). Land reclamation influences peat formation and decomposition processes by lowering litter input rates and water table level (Laiho *et al.*, 2006). This has likely led to changes in peat organic carbon chemistry (OCC). To achieve sustainable utilization of reclaimed peatlands, increased understanding on OCC at various land management types is needed in order to improve land management towards increased sustainability. With this study we aim to answer following questions: (i) Does land-use change affect tropical peat OCC? (ii) How does land-use change affect OCC? (iii) What kind of implications could changes in OCC cause to carbon dynamics at various land-use types?

MATERIALS AND METHODS

To study tropical peat OCC we collected soil samples from an undrained peat swamp forest and three sites altered 20–30 years prior to the study. The included land uses form a continuum of increasing land-use intensity (undrained forest; drainage-affected forest; drained, deforested degraded open site; drained, deforested, site under cultivation) in Central-Kalimantan, Indonesia. Information of central peat properties from the sites are presented in Table 1 (Könönen *et al.*, 2015). Sampling depths below the peat surface covered mostly oxic (-10 cm), frequently waterlogged (-45 cm for undrained forest; -45 cm and -80 cm for altered sites) and permanently waterlogged, anoxic conditions (-80 cm for undrained forest, -110 cm for altered sites). To study peat OCC, we analyzed the total concentrations of hemicellulose, of extractives, cellulose, acid-soluble lignin (ASL) and acid-insoluble residue (AIR) in peat. The total hemicellulose concentration included non-cellulosic polysaccharides formed of combination of concentrations of neutral sugars (arabinose, rhamnose, xylose, mannose, galactose, glucose) and uronic acid (glucuronic, galacturonic and 4-O-Me-glucuronic acids). The composition of hemicelluloses and uronic acids were analyzed with method described in Sundberg *et al.* (1996) and composition of

celluloses with method described in Sundberg *et al.* (2003). The concentration of extractives was analyzed using acetone:water solution (v:v, 9:1). The concentration of AIR was analyzed with a standard procedure (TAPPI Test Method T 222-om-88, 2000), and the solution for analyzing ASL concentration was formed as by-product in AIR analyses and analyzed using UV spectroscopy at an absorbance of 203 nm (Brunow *et al.*, 1999).

Table 1: The average dry bulk density (BD g cm^{-3}), proportion of different sized fractions in peat (presented as percentage from BD), total C and N concentration, and C/N-ratio for peat from the study sites. Data published in Könönen *et al.* (2015).

Site	BD, g cm^{-3}	<0.15 mm, %	0.15-1.5 mm, %	>1.5 mm, %	C, %	N, %	C/N-ratio
Undrained forest	0.140	51.15	36.90	11.58	58.11	1.35	47.62
Drained forest	0.164	45.29	44.22	9.30	59.72	1.09	62.97
Degraded, open site	0.153	57.97	34.74	9.56	58.48	0.78	75.92
Agricultural, open site	0.152	60.73	27.10	8.53	58.69	0.80	74.92

RESULTS

In forest sites the average total hemicellulose, extractives, and ASL concentrations were higher (646.7%, 37.8% and 56.1%, respectively) and total cellulose and AIR concentrations were lower (3.6% and 11.3%, respectively) than at the open sites (Figure 1). The greatest difference in OCC between the two forest sites occurred at 40-45 cm depth, where peat from drained forest had less hemicellulosic carbohydrates and more extractives, and it started to have increasingly similar characteristics with the peat in open sites (Figure 1 and Figure 2). The hemicellulose concentration was higher in the forest than in the open sites, but the non-cellulosic polysaccharides were present in following order: glucose > xylane > mannose > galactan > galacturonic acid >arabinose > rhamnose > glucuronic acid > 4-O-Me-glucuronic acid (Figure 2). The peat hemicellulosic concentration decreased with depth at the forest sites, but the concentrations was low and rather constant at the open sites' peat profiles.

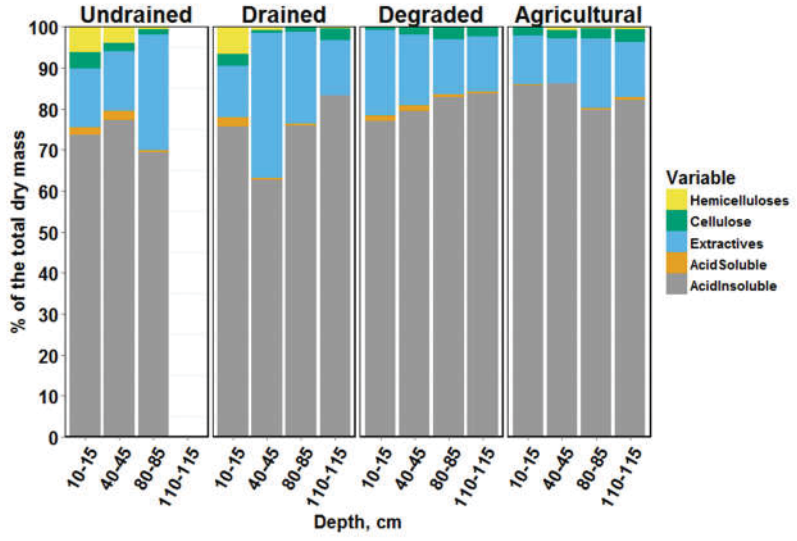

Figure 1: Cumulative proportional (%) concentration of hemicelluloses, cellulose, extractives, acid soluble lignin and acid insoluble residue in peat from various land management types and depths.

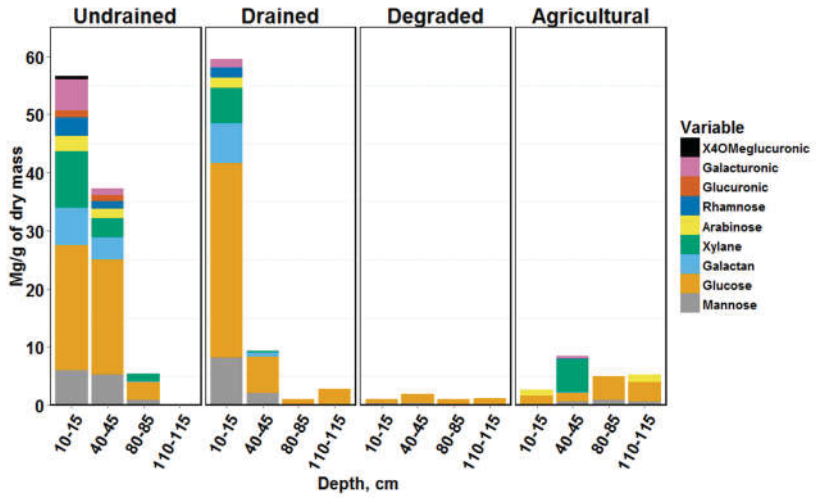

Figure 2: Cumulative concentration (mg g^{-1} in dry peat) of uronic acids (glucuronic, galacturonic and 4-O-Me-glucuronic acids) and neutral sugars (arabinose, rhamnose, xylose, mannose, galactose, glucose) in peat from various land management types and depths.

DISCUSSION

Our results show that land-use change leads to enrichment of recalcitrant OCC in peat, and the effects are greater when both water table level is permanently lower level and the original forest vegetation is removed. The peat AIR concentration was generally higher in comparison to boreal *Sphagnum* peats (Andriesse, 1988), and it is consistent with woody characteristics of organic matter forming peat (Yule & Comez, 2009; Mehta *et al.*, 2013). In the forest sites the main litter (i.e. roots, leafs and branches) deposition occurs close to peat surface (Page *et al.*, 1999; Sulistiyanto 2004; Wüst *et al.*, 2008), and as a consequence of progressive decomposition the concentration of labile carbohydrates decrease and recalcitrant polymers increase with increase in distance from peat surface at the forest sites.

Deforestation leads to permanently reduced vegetation biomass and litter deposition rates, which together with improved conditions for aerobic decomposition due to water-level drawdown. This management driven condition has led to the detected increase of recalcitrant compounds in the topmost surface peat. At the open sites, also recurrent fires modify peat structure and composition (see Könönen *et al.*, 2015). At the study sites at open areas it has been estimated that c. 50 cm of surface peat has disappeared due to fires (Hoscilo *et al.*, 2011). Fires have exposed and resurfaced aged and thus more decomposed peat, but also modified surface peat properties. Especially at the agricultural site the AIR concentration at the depth of -10 cm was high, which is likely due to management fires and soil tilling that mix the surface peat layer and transport this most decomposed top peat deeper in the profile.

The peat properties altered in land reclamation change decomposability properties in the substrate. Due to progressive enrichment of recalcitrant compounds in peat, the gaseous C emissions have been noticed to decrease in with time after land reclamation. This can be explained by decreased availability of labile carbohydrates, which are providing easier energy source for the peat decomposition resulting microbes. Yet, reintroducing labile C and N substrates (i.e. fertilization) may induce decomposition process at the open sites with more recalcitrant peat (see Jauhiainen *et al.* this volume).

CONCLUSION

Land-use change leads to enrichment of recalcitrant carbon compounds over time, especially when both deforestation and drainage are included. Due to maintained continuous litter input, in forest covered peatlands the total hemicellulosic concentration at surface peat can remain high despite the drainage. In reclaimed sites, fires and lack of litter input leads to progressive enrichment of recalcitrant compounds at the surface peat.

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