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THE EFFECT OF WATER TABLE RISING ON NUTRIENT AND DISSOLVED ORGANIC CARBON (DOC) RELEASE FROM RESTORED PEATLAND FORESTS

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SUMMARY

Earlier studies have shown contradictory results concerning the impacts of peatland restoration on nutrient and DOC transportation. To clarify these results, we studied the effect of water table (WT) rising on phosphorous (P), iron (Fe), ammonium ($NH4^+$-N), nitrate ($NO3^-$-N), and dissolved organic carbon (DOC) mobilization with a laboratory microcosm incubation experiment. Peat soil samples were collected from two blanket bogs in Ireland and five contrasting sites in Finland. The results indicated significant differences in P, N, and DOC release due to water-logging, with from almost no increase to over hundred-fold increase compared with the columns subjected to aerobic conditions.

KEYWORDS: Restoration, incubation experiment, DOC, nutrient mobilization

INTRODUCTION

Up to 60% of pristine European peatlands have been drained or altered. In some countries, such as Great Britain, France, Germany, the percentage is up to 90. Human-induced changes consist of about 50% for agriculture, 30% for forestry and 10% for peat extraction. (Joosten, 1997).

Today, ecosystem services, protection of key biotopes, and failure to grow economically sustainable forest on peatlands have created needs and pressure to restore drained peatlands to natural mire ecosystems. Currently there are international efforts to protect peatlands or to rehabilitate their functions in the landscape through restoration measures (Erwin, 2009).

However, peatland restoration can have detrimental effects on the quality of runoff water and recipient water courses. The fact that headwaters near restoration areas have already been affected by peatland drainage in the 20th century stresses the importance of avoiding further loading (Koskinen et al., 2011).

The major adverse hydrological impact of restoration of drained peatlands is the increased leaching of phosphorus (Sallantaus 1999, Zak et al. 2010, Koskinen et al. 2011), although minor or negligible increases have also been reported (Vasander et al. 1998, Urbanová et. al., 2010). In addition, active restoration work such as filling-in the ditches and cutting the tree stand have been shown to initially lead to highly increased nitrogen (N) and dissolved organic carbon (DOC) exports (Zak et al. 2010, Koskinen et al. 2011, Urbanová et. al., 2010).

These somewhat contrasting results require further research. To clarify these results, we studied the effect of water table (WT) rising on phosphorous (P), iron (Fe), ammonium ($NH4^+$-N), nitrate ($NO3^-$-N), and dissolved organic carbon (DOC) mobilization with a laboratory microcosm incubation experiment.

The study focuses on peatlands drained for forestry in Finland and Ireland. Almost one-third of the European (EU) peatland resource is in Finland (Montanarella et al. 2006), and more than half of it has been drained, mostly for forestry. Ireland possesses significant portion of the world's blanket bogs and is one of the most important country in Europe for this type of habitat (Sottocornola and Kiely, 2005). However, there is only 20% of the original area remaining in a relatively intact condition (Foss and O´Connell, 1998).

MATERIAL AND METHODS

During the experiment peat was incubated in water-tight PVC pipes at 18 ^oC for about 7 months. Four columns per site were incubated under anaerobic waterlogged conditions and four under approximate field soil moisture content with low water table. Soil water samples were taken fortnightly or once a month from the approximate depth of 10-20cm. Samples were taken using suction samplers with a polymeric tip of 9 cm in length and 4.5 mm in diameter, attached to a removable syringe generating approximately a suction of 100 kPa.

The soil samples for the pipes were collected from five contrasting sites in Finland and two sites in Ireland. The experiment was carried out concurrently in both countries.

In Finland, the peat samples were collected from three ombrotropic sites: ombrotrophic highly decomposed (O_{HUM}), ombrotrophic slightly decomposed (O), ombrotrophic ash-fertilized (O_{ASH}), and two minerotrophic sites: oligotrophic peat from moderately productive site (M_{OLIG}) and highly nutrient-rich and decomposed peat from highly productive site (M_{MESO}). In Ireland, peat samples were collected from highly decomposed blanked bog (B_{HUM}) and moderately decomposed blanked bog (B).

RESULTS

The results indicated significant differences in P, N, and DOC release from water-logged (high water table) columns, ranging from almost no increase to over hundred-fold increase compared with the columns at approximate field moisture content (low water table).

In Finland, P release was significantly higher from the rewetted ombrotrophic than the minerotrophic peats (Fig. 1). From the minerotrophic M_{OLIG} peat, P mobilization was virtually negligible. Fe, DOC, and $NH4^+$-N were released from the most nutrient rich, M_{MESO} peat (Fig. 1). In Ireland, release of all nutrients ($NH4^+$-N, Fe, P) and DOC was significantly higher from highly decomposed blanked bog peat than from less humified peat (Fig. 1). NO3-N concentrations increased only in the peat columns with low water table.

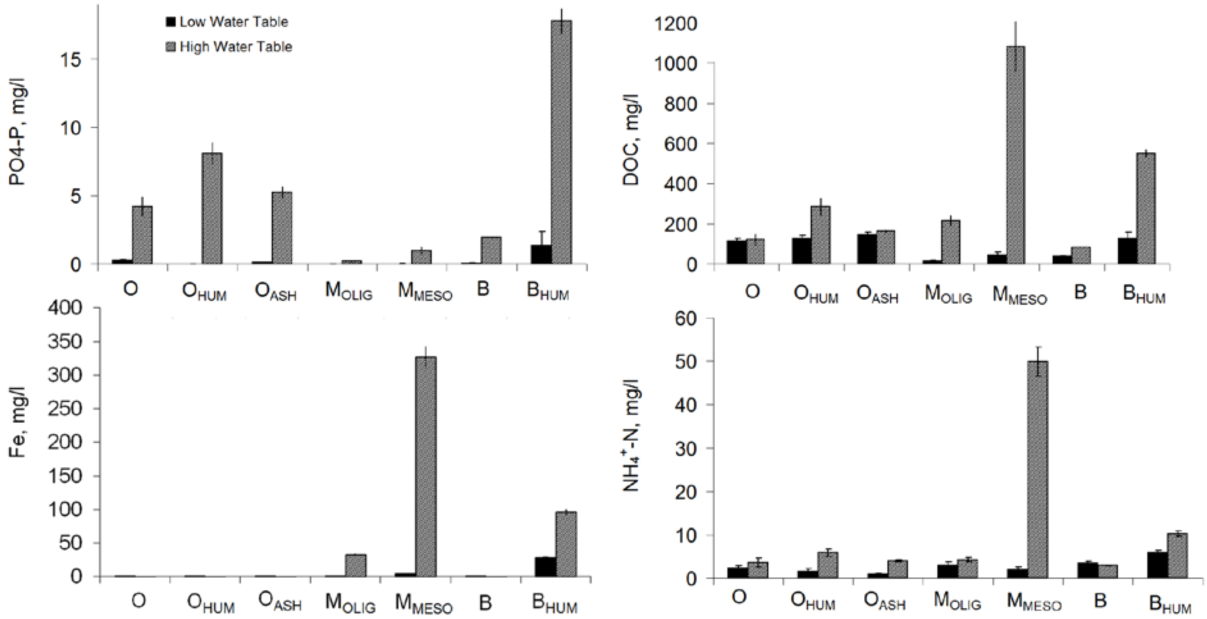

Fig. 1. Microcosm incubation: release of PO4-P , Fe, DOC, NH_4^+-N, and NO_3-N under water-logged and aerobic conditions. O_{HUM}: ombrotrophic highly humufied peat (Finland), O: ombrotrophic slightly decomposed (Finland), O_{ASH}: ombrotrophic ash-fertilized peat (Finland) M_{OLIG}: oligotrophic peat from moderately productive minerotrophic site (Finland), M_{MESO}: highly nutrient-rich and decomposed peat from highly productive minerotrophic site (Finland): B_{HUM}: highly decomposed blanked bog peat (Ireland), B: moderately decomposed blanked bog peat (Ireland).

DISCUSSION

Observed higher P release from the rewetted ombrotrophic than the minerotrophic peats in Finland is consistent with earlier studies (Koskinen et al. 2011). High release of P is most likely due to ombrotrophic peat soils having very low concentrations of iron and aluminum hydroxides or oxides, and therefore very low phosphate adsorption capacity (Kaila, 1959; Nieminen and Jarva, 1996).

Mobilization of Fe suggests that the peat contains iron and consequently P retention capacity (Fig 1). In mineral soils, reduction of Fe(III) to Fe(II) under water-logged and low redox potential conditions may lead to enhanced mobilization of P (Morris and Hesterberg, 2010; Zak et al., 2010). In addition, Morris and Hesterberg (2010) showed that increases in both pH and dissolved organic matter during reduction of soils likely contribute to phosphate dissolution and diminished phosphate retention capacity in reduced soils.

Release of NO_3-N mostly from the minerotrophic peats under aerobic conditions indicates nitrification potential. Urbanová et. al. (2010) suggested that due to low nitrification rate also denitrification will become a less important process at restored peatlands. Most mineral N will be present either in the form of NH_4^+ or organic forms. The observed higher NO_3-N release from minerotrophic peats is consistent with earlier studies showing enhanced nitrification after lowering of the water table in minerotrophic peat but not in ombrotrophic peat (Regina et al. 1996).

High release of Fe and ammonium observed on M_{MESO} peat and to some extent on B_{HUM} peats indicate high microbial metabolism (Zak et al., 2010). The increase of DOC concentrations was also highest for these peats. The release of DOC into soil is as a result of oxidative degradation of plant-derived organic matter combined with production of microbial metabolites (Guggenberger et al**.** 1994). It has been shown that leaching of dissolved organic carbon increases for some time after restoration, when increased amounts of water reach the decomposed surface peat of the drained area. Our results are consistent with the study by Koskinen et al. (2011). They found higher ammonium release and temporary TOC release from nutrient-rich spruce mire area compared with nutrient poor area after restoration.

To explain the between-site differences in element release due to water-logging, the peats incubated in the columns and parallel peat samples collected before incubation will be analysed for the different biogeochemical forms of P, N, and C, such as microbiologically bound forms using the fumigation-extraction method, and aluminum, iron and calcium bound P using the modified Chang and Jackson sequential fraction procedure (Hartikainen, 1979). Also, samples of dissolved organic matter (DOM) will be collected to analyse them for the degradability and characteristics of DOM, as well as the distribution of N and C into fractions according to chemical nature and molecule size as in Kiikkilä et al. (2011).

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