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PHOSPHORUS IN PEAT SOILS AND RISK FOR LEACHING AFTER REWETTING OF DRAINED PEATLANDS

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SUMMARY

The effect of land-use on phosphorus in peat soils and risk for phosphorus leaching during rewetting of the site was studied in this research. Peat samples were taken from peatlands with different land uses. Samples were taken from cultivated site, peatland forest, peat extraction site and pristine mire at different depths. The samples were analyzed for easily soluble phosphorus, aluminum, iron and calcium bound phosphorus by Chang and Jackson sequential fractionation method. The risk of phosphorus leaching was estimated in desorption experiments and by measuring degree of phosphorus saturation (DPS). The cultivated site showed high total concentrations of P, Fe and Al compared to other land uses. P fractionation showed that inorganic P in the cultivated site was mainly associated with iron and aluminum. The degree of phosphorus saturation (DPS) measured in the surface of the cultivated site was high (25.6 %) indicating high risk for P leaching, which was also seen in the desorption test.

KEY WORDS: phosphorus in peat, land use, phosphorus leaching, restoration

INTRODUCTION

Restoration of drained peatlands is an important tool to improve biodiversity in the boreal peatlands, to reduce greenhouse gas (GHG) emission, re-establish nutrient and water retention capacity and restore the cultivated field after agriculture is no longer possible. However, restoration of drained peatlands by rewetting can have negative effects on runoff water quality, since release of phosphorus (P) from peat soils has been reported after rewetting (Kiekbusch and Schrautzer, 2007; Niedermeier and Robinson, 2009). Phosphorus is often the limiting nutrient in surface watercourses in Finland, therefore P leaching can cause eutrophication in down-stream watercourses. This results in increased primary production which can be seen as algal blooms, increased turbidity and lack of oxygen in the water. More information is needed to clarify peatland management options and to avoid negative impacts on water quality.

The leaching of phosphorus from peatlands depends on its chemical form in peat. Therefore analyzing the distribution of various forms of inorganic phosphorus in peat provides valuable knowledge about risk of phosphorus leaching, which helps to design restoration acts. The objective of this research was to study the effect of land use on quantity and forms of phosphorus in peat soils and to estimate the risk of phosphorus leaching from peatlands.

MATERIAL AND METHODS

Sampling and laboratory analyses

Peat samples were taken from a mire with different peatland uses. Samples were taken from a cultivated site, a peatland forest, a peat extraction site and a pristine bog at different depths (0-75 cm, also 75-140 cm from the bog).

Peat samples were analyzed for total P using hydrochlorid acid (HCl) extraction (Andersen, 1976). For the analysis, 2-3 g of peat was ignited at 550^{o}C in muffle furnace for 3 h and the ash was extracted with 6 M HCl. The extracts were analysed by ICP-OES in Finnish Environment Institute.

To study how P is bound to the peat, phosphorus was fractionated into easily soluble and loosely bound P, and Al-, Fe- and Ca bound P according to the method of Chang and Jackson (1957). The method consisted of sequential extraction of 1.0 g peat with 50 ml of 1 M NH_4Cl (extraction time 30 min), 0.5 M NH_4F (1 h), 0.1 M NaOH (16 h), and 0.25 M H_2SO_4 (1 h). PO_4-P was analyzed using molybdenum blue method. The analyses were carried out in duplicate and all solutions were prepared using high purity 18 MΩcm^{-1} water (Milli-Q, Millipore).

The risk of phosphorus leaching during rewetting was estimated in desorption test and by measuring degree of phosphorus saturation (DPS) in peat samples. The desorption test was performed with samples taken from the surface (0-15 cm) of the cultivated site and the peat extraction site. Soil to solution ratio of 1:60 was used in the experiment i.e. 25 g (dry weight) of peat and 1500 ml distilled water was placed into the plastic bottles. The water was bubbled with N_2 gas to remove the oxygen. Water samples were filtered through Millipore 0.45 µm filter paper and PO_4-P was analyzed using molybdenum blue method.

The degree of phosphorus saturation was determined by acid ammonium oxalate extraction. Approximately 8 g of wet peat was weighed to plastic bottles and extracted with 60 ml of oxalate solution for 2 h at room temperature (20°C). The samples were centrifuged with 4000 rpm for 10 minutes and the supernatant was filtered and oxalate extractable P, Fe and Al were analyzed by ICP-OES in Finnish Environment Institute.

The degree of phosphorus saturation was calculated using the oxalate extractable P, Fe and Al:

$$\text{DPS}\ (\%) = \frac{P_{ox}}{0,5 * (Al_{ox} + Fe_{ox})}$$

where P_{ox}, Al_{ox} and Fe_{ox} are oxalate extractable P, Al and Fe (mmol kg^{-1}).

RESULTS

Cultivated site showed high total concentrations of P, Fe and Al compared to other land uses. Average P_{tot} concentration in cultivated site soil profile was 1172 mg kg^{-1} (Table 1), which was two times higher compared to the peatland forest and the peat extraction site and four times higher compared to the pristine mire. The average concentration of Fe_{tot} was lowest in the pristine mire being only 11 % of that in the cultivated site. The average concentration of P_{ox} was also higher in the cultivated site (377 mg kg^{-1}) compared to other land uses (Table 1).

Table 1. Average concentrations in soil profiles of different land uses (mg kg^{-1})

Site	P_{tot}	Fe_{tot}	Al_{tot}	P_{ox}	Fe_{ox}	Al_{ox}
Cultivated peatland	1172	12425	3340	377	8647	1783
Peatland forest	647	8066	818	40	7229	475
Peat extraction site	589	8087	2314	51	7529	1666
Pristine mire	330	1334	746	9	1117	480

The sequential phosphorus fractionation showed that inorganic P in the cultivated peat soil was mainly bound to iron and aluminum. The Al-P and Fe-P fractions were highest in the surface of the cultivated site and decreased with increasing depth in the soil profile. The concentration of the inorganic Ca-P fraction was low in all layers (below 4 mg kg^{-1}). However, slightly higher concentration of Ca-P was observed in the surface compared to other layers. The soluble and loosely bound P fraction was also low in all peat layers.

The degree of phosphorus saturation (DPS) measured in the surface of the cultivated site was high (25.6 %) compared to other land uses (Table 2). The lowest DPS was found in the surface of the peat extraction site (2.2 %).

Table 2. Degree of phosphorus saturations in the surface layer of different land uses

Site	DPS (%)
Agricultural field	25.6
Peatland forest	3.4
Peat extraction	2.2
Pristine mire	3.6

Desorption test showed that phosphorus was leached from the cultivated soil to the water in anaerobic conditions (Figure 1). In the beginning of the test, desorption was highest but it continued through the study period. At the end of the test (after 84 days) 20 mg P kg^{-1} soil was leached to the water phase. Total desorption followed well exponential equation $y=2{,}009x^{0{,}5256}$ with $R^2=0{,}98$. Leaching of phosphorus was clearly lower in peat extraction site; only below 1 mg P kg^{-1} soil was leached after 42 days (Figure 2). Total desorption did not follow any equation. The proportion of leached P of total P in peat in the cultivated site was 1.5 % and in the peat extraction site 0.2%.

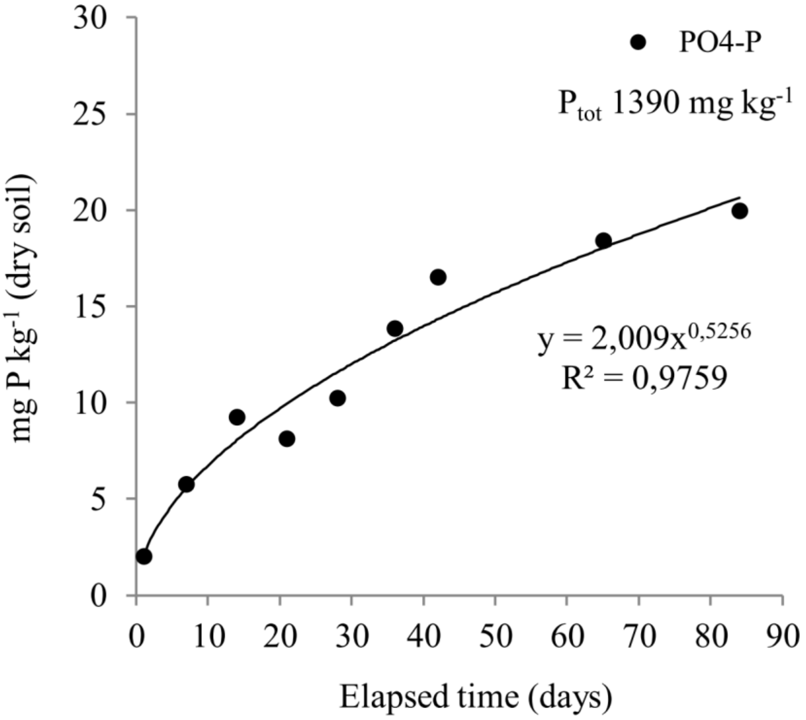

Fig. 1. Cumulative desorption of phosphorus (PO4-P) from cultivated site surface layer (0-15 cm) in anaerobic conditions.

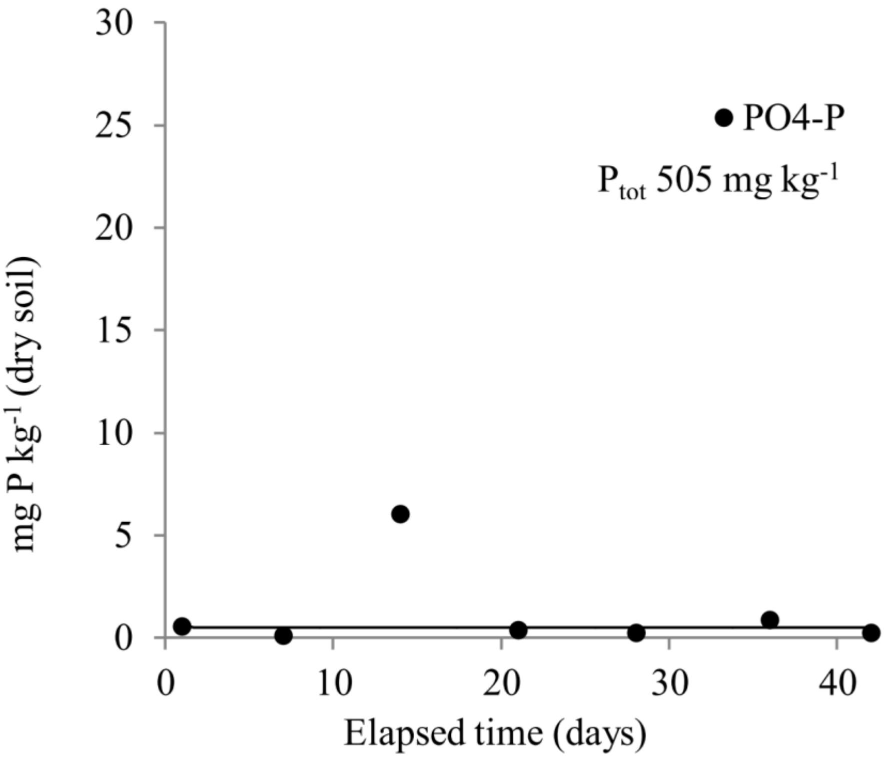

Fig. 2. Cumulative desorption of phosphorus (PO_4-P) from peat extraction site surface layer (0-15 cm) in anaerobic conditions.

CONCLUSIONS

The cultivation practices have increased the P content in the cultivated site; the average concentration of P_{tot} was two times higher compared to the peatland forest and the peat extraction site and four times higher compared to the pristine mire. The elevated P concentrations in the cultivated site are a result of fertilizer and liquid manure application to the field.

Most of the phosphorus in peat was associated with aluminum and iron. Slightly higher concentration of Ca bound P in the surface of the cultivated site is due to liming of the site. The accumulation of phosphorus to the surface of the cultivated peat soil can be seen as high phosphorus saturation degrees in the soil. DPS in the surface of the cultivated site was 25.6% indicating high saturation and therefore high risk of leaching, which could be also seen in the desorption test. Release of P from peat soil after rewetting can pose a risk to adjacent water quality. On the contrary, DPS in the peat extraction site was low and desorption test showed lower leaching of P to the water.

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