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EFFECTS OF DIFFERENT PEATLAND MANAGEMENT OPTIONS ON CO_2 EMISSIONS AND PHYSICAL PROPERTIES OF PEAT

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SUMMARY

Aim of this study was to determine effects of different land uses on physical properties of peat and CO_2 emissions from peatland sites. An undrained bog and peatland sites drained for agriculture, forestry and peat extraction were studied. In the agricultural site and the peat extraction site, top layer of soil was compressed, and in the agricultural site, addition of sand caused high ash content in the top soil. CO_2 fluxes from the agricultural site were the highest, but decreased after harvest of grass. CO_2 fluxes were positively correlated with air and soil temperature and negatively correlated with soil humidity.

KEYWORDS: peat physical properties, effects of land use, CO_2 emissions

INTRODUCTION

Agricultural peatlands are a major source of CO_2 and N_2O emissions in Nordic countries (Kasimir-Klemedtsson *et al.*, 1997). Also peatlands drained for peat extraction act as sources of CO_2, whereas sites drained for forestry are net sinks and undrained sites can be either sources or sinks (Maljanen *et al.*, 2010). Agricultural peatland sites need to be managed or restored so that decrease of the GHG emissions is maximized while negative effects such as phosphorus leaching are minimized. For this, information about peatland soil physical properties is needed. Physical properties vary greatly depending on land use and peat type. Ash content and bulk density of peat are known to increase and porosity decrease after drainage because of compression and increased decomposition of peat (Kechavarzi *et al.*, 2010).

The aim of this study was to find out how different land uses affect physical properties of peat and CO_2 emissions from peatland sites. Another objective was to produce new information on general peat physical properties (e.g., for modeling).

MATERIALS AND METHODS

Five study sites were included in this study. All the study sites were originally part of the same Pelso peatland complex that was drained late 1800s onward. One of the sites, an undrained bog (Kallioneva), was close to natural state and used as reference sites. The bog was *Sphagnum* dominated, with peat depth between 1 and 2 m (Häikiö, 2008). Peat decomposition in the bog varied from H1 to H10 in von Post scale. Two of the sites were peatlands drained for forestry, peat depth less than 75 cm at one site (site Forest A) and over 75 cm at the other site (site Forest B). Water level in the site B varied between 10 cm and 50 cm depth during summer 2011. Both forest sites were drained in 1970s but only Forest A has been fertilized with N fertilizers twice since. Agricultural site was drained in 1930s and has been in 3-4 year rotation of grass (3 a) and barley (1 a) ever since. Peat extraction site (Pelsonrimpi II) was drained in 2006 (into production in 2007), before which it was poorly drained peatland area with some trees. Following draining, soil surface went down for about 50 cm due to compression, and in the 4 years the site was in production, about 40 cm of peat were taken away. Samples were taken in two different locations in this site.

Porosity and bulk density were measured from samples taken in sharpened steel cylinders of known volume (diameter 4 cm, volume 50 cm^3, number of samples 131). Samples were first weighed at natural moisture content, then after saturating with water, and finally after drying in oven of 70° C for 24 hr and 105° C overnight. Ash content was determined from these samples, and additionally from disturbed samples taken in same depths as the undisturbed samples, by burning them in 550° C (CEN/TS 14775:2004).

CO_2 emission (total respiration of soil and plants) rates were measured weekly at four study sites (undrained bog, agricultural field, Forest B, peat extraction site; 4-5 measuring points/agricultural sites, 3 points for the other sites) from July 2011 to September 2011 using opaque non-steady-state chamber (closed static chamber). The CO_2 flux was calculated from the rate of concentration increase in the chamber (determined using VAISALA CARBOCAP® Carbon Dioxide Probe GMP343 device) in certain period of time (about 5 min). Soil temperature, soil moisture and air temperature and air humidity were measured during the CO2 measurement. Furthermore, air temperature, air humidity and ground water level were monitored continuously. Total 154 flux measurements were made.

RESULTS

Physical properties

In all study sites except the undrained bog Kallioneva, average von Post values were 4-5 in the top 60 cm of soil (Table 1). In the forest B, the values varied from 3 to 5, in the agricultural site from 4 to 6, in the peat extraction site from 3 to 6, and in the undrained bog, 1 to 10. In the agricultural site and the peat extraction site, von Post values increased with depth, while in the forest B the von Post values were highest in the 0-15 layer and decreased with depth until 60-75 cm layer. In the bog, surface layer (0-15 cm) was living layer with mostly *Sphagnum* moss, the middle layer (15-75 cm) was slightly decomposed (von Post 3-4) and from 75 cm downwards soil was highly decomposed peat with von Post value up to 10.

In both layers 0-15 cm and 15-60 cm, the greatest ash content and bulk density were found in the agricultural site (Table 1). As expected, lowest values were found in the undrained bog, where also porosity was highest. Values from the forest sites and the peat extraction site were between these extremes. In the peat extraction site and the agricultural site, there was a clear decrease in ash content and bulk density from top 15 cm to 15-60 cm layer. In the bog and the forest, difference between the two layers was not as clear.

Table 1. Mean, standard deviation (σ) and number of samples (N) for physical properties of the Pelso study sites in different land uses. Measured physical properties include von Post humification, ash content (mg/cm^3), ash content (m-%), bulk density (g/cm^3) and porosity (cm^3/cm^3)

Depth: 0-15 cm		von Post humification	Ash content [mg/cm^3]	Ash content [m-%]	Bulk density [g/cm^3]	Porosity [cm^3/cm^3]
Forest	mean	4.5	3.98	2.84	0.14	0.86
	σ	0.0	1.04	0.55	0.02	0.03
	N	4	10	10	10	10
Agricul-tural	mean	4.0	326.74	65.54	0.5	0.7
	σ	0.0	99.17	20.68	0.06	0.04
	N	16	16	16	16	16
Bog	mean	1.2	0.62	1.23	0.05	0.96
	σ	0.3	0.31	0.62	0	0.01
	N	6	6	6	6	6
Peat extraction	mean	4.6	18.41	9.34	0.21	0.84
	σ	0.7	29.67	16.08	0.05	0.04
	N	6	14	14	15	15

Depth: 15-60 cm		von Post humification	Ash content [mg/cm^3]	Ash content [m-%]	Bulk density [g/cm^3]	Porosity [cm^3/cm^3]
Forest	mean	3.9	3.11	2.38	0.13	0.86
	σ	0.3	0.79	0.48	0.02	0.03
	N	20	26	26	26	26
Agricul-tural	mean	4.3	54.44	16.72	0.22	0.81
	σ	0.4	87.91	19.83	0.1	0.05
	N	36	36	36	36	36
Bog	mean	2.0	0.63	1.06	0.06	0.99
	σ	0.2	0.28	0.55	0.01	0.05
	N	21	20	21	21	21
Peat extraction	mean	4.5	4.84	2.95	0.16	0.89
	σ	0.6	1.79	0.7	0.03	0.04
	N	18	36	39	39	39

CO_2 fluxes

CO_2 flux from the agricultural site was clearly higher than the flux from the other sites (mean 1119 mgCO_2 m^{-2} hr^{-1}) (Table 2). Also variation of the flux was the greatest in the agricultural site (Fig. 1), and the flux decreased by half after harvest of the grass in August. Smallest fluxes were from the undrained bog (mean 164 mgCO_2 m^{-2} hr^{-1}).

Table 2. Mean, standard deviation (σ) and number of samples (N) for CO_2 fluxes measured in Pelso study sites (July 14, 2011 - September 29, 2011)

Land use	mean CO_2 flux (mgCO_2 m^{-2} hr^{-1})	σ	N
Forest	232	100	36
Agricultural	1119	725	47
Bog	164	224	35
Peat extraction	219	218	36

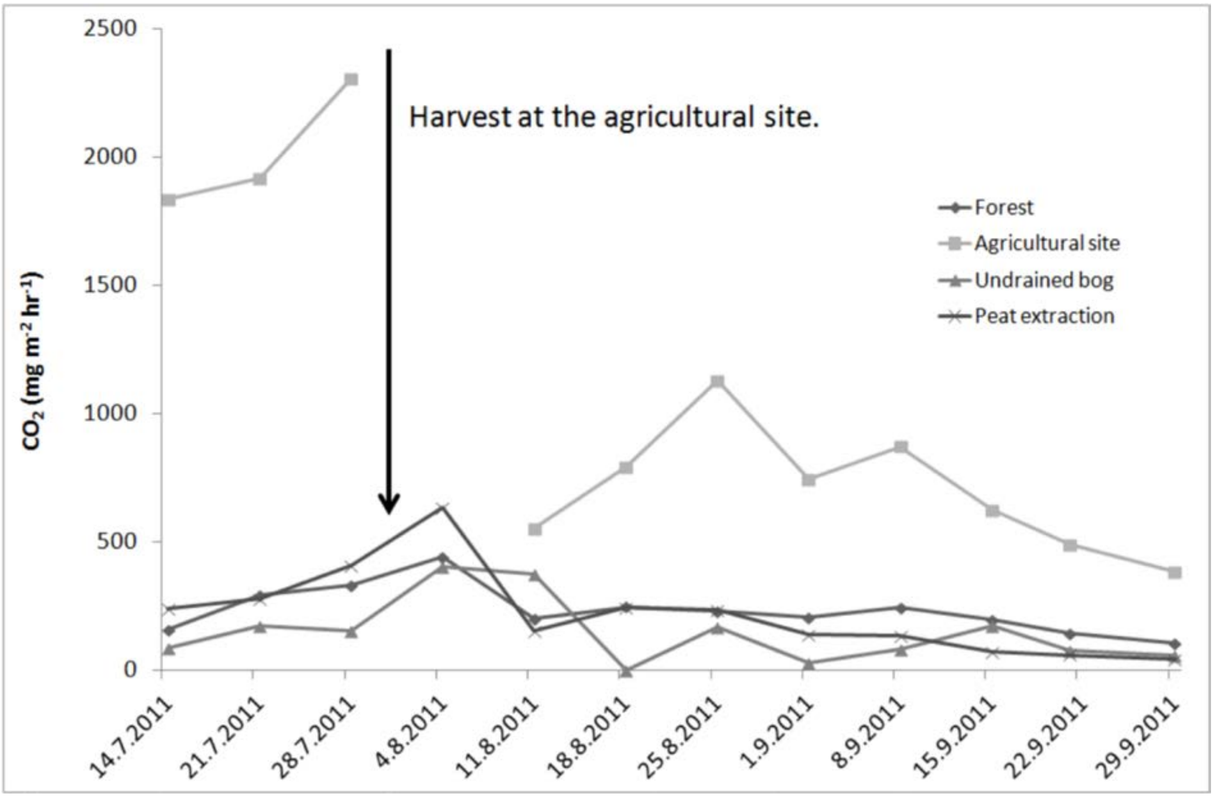

Fig. 1. Mean CO_2 fluxes measured in Pelso study sites in different land uses (July 14, 2011 - September 29, 2011).

DISCUSSION

The high ash content in the top 15 cm of soil in the agricultural site was due to sand added to improve cultivation properties of the field. This used to be a common practice in agricultural peatlands in Finland (Myllys, 1998). The ash content was six times higher than in 15-60 cm layer, and 18 times more than in top layer of peat extraction site and over 82 times higher than in top layer of forest. Same can be seen in ash content mass per mass dry matter. Also dry bulk density in surface layer of the agricultural site was great: 2 times higher than in 15-60 cm layer, over 2 times higher than in top layer of peat extraction site and over 3 times higher than in top layer of forest.

It is probable that surface layers in peat extraction site and agricultural site are compressed by the heavy machinery used on the sites and collapse of peat structure with drainage. The porosity in these surface was lower than in the deeper layers even when peat in the deeper layers was the same or even greater in von Post value. In the forest sites, draining has probably caused some increase in decomposition in topmost layer, as indicated with higher von Post value, lower porosity and higher bulk density and ash content.

Harvest of the grass in the agricultural site had significant negative effect on the CO_2 fluxes although even after the harvest, fluxes from the agricultural site were significantly higher than from the other three sites. CO_2 fluxes have a significant ($p<0.05$) positive correlation with von Post value, ash content and bulk density in top 15 cm of soil, and a significant negative correlation with porosity. Furthermore, CO_2 fluxes have a significant positive correlation with soil temperature and air temperature for all sites except the bog where the correlation between CO_2 flux and the air and soil temperatures were positive but not statistically significant. Also in all sites correlation between CO_2 flux and soil moisture was negative ($p<0.05$). Significant positive correlation was also found with air humidity in all sites but bog where correlation was negative and not significant. This is in agreement with literature (e.g. Davidson *et al.*, 1998) where soil temperature is found to be one of the major factors that affect positively CO_2 production, and where CO_2 production was found to decrease with increasing soil moisture.

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REFERENCES

Davidson, E.A., Belk, E. and Boone, R.D. (1998). Soil water content and temperature as independent or confounded factors controlling soil respiration in a temperate mixed hardwood forest. *Global change biology* 4, 217.

Häikiö, J. (2008). *Vaalassa tutkitut suot ja niiden turvevarat,Osa 1 (Mires investigated in Vaala and their peat reserves, part 1)*. Report of Peat Investigation 383, 91 pp. Kuopio, Geological survey of Finland.

Kasimir-Klemedtsson, A., Klemedtsson, L., Berglund, K., Martikainen, P., Silvola, J. and Oenema, O. (1997). Greenhouse gas emissions from farmed organic soils; a review. *Soil Use Manage* 13, 245-250.

Kechavarzi, C., Dawson, Q. and Leeds-Harrison, P. (2010). Physical properties of low-lying agricultural peat soils in England. *Geoderma* 154, 196-202.

Maljanen, M., Sigurdsson, B. D., Guðmundsson, J., Óskarsson, H., Huttunen, J. T. and Martikainen, P.J. (2010). Greenhouse gas balances of managed peatlands in the Nordic countries - present knowledge and gaps. *Biogeosciences* 7, 2711-2738.

Myllys, M. (1998). Soiden viljely (Cultivation of mires). In H. Vasander (ed.), *Suomen suot (Mires of Finland)*. 168 pp. Helsinki, Suoseura.