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Fluxes of nitrous oxide and methane on an abandoned peat extraction site: Effect of reed canary grass cultivation

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ABSTRACT

Drained organic soils are among the most risky soil types as far as their greenhouse gas emissions are considered. Reed canary grass (RCG) is a potential bioenergy crop in the boreal region, but the atmospheric impact of its cultivation is unknown. The fluxes of N_2O and CH_4 were measured from an abandoned peat extraction site (an organic soil) cultivated with RCG using static chamber and snow gradient techniques. The fluxes were measured also at an adjacent site which is under active peat extraction and it is devoid of any vegetation (BP site). The 4-year average annual N_2O emissions were low being 0.1 and 0.01 g N_2O m^{-2} a^{-1} at the RCG and BP sites, respectively. The corresponding mean annual CH_4 emissions from the RCG and BP sites were also low (0.4 g and 0.9 g CH_4 m^{-2} a^{-1}). These results highlight for the first time that there are organic soils where cultivation of perennial bioenergy crops is possible with low N_2O and CH_4 emissions.

1. Introduction

As part of the Kyoto protocol, signatory member countries are required to reduce their greenhouse gas emissions. One of the mitigation strategies is to increase the proportion of renewable energy sources, such as biomass from bioenergy crops in the total energy consumption. Bioenergy crop production; however, can have such high emissions of nitrous oxide (N_2O) and methane (CH_4) that the beneficial effects of replacing fossil fuel with biomass can be questioned (Adler et al., 2007; Crutzen et al., 2008; Smith et al., 2001). N_2O and CH_4 are important greenhouse gases because according to the global warming potential (GWP) approach, N_2O is 298 and CH_4 25-times (time horizon of 100 years IPCC, 2007) more effective as a greenhouse gas than CO_2.

Peatlands have been drained for forestry, agriculture or peat extraction (Turunen, 2008). In Finland, about 3000 ha is released each year for peat extraction (Salo and Savolainen, 2008). After peat extraction these areas can be afforested, rewetted or used for agricultural purposes including bioenergy crop cultivation. Perennial crops such as reed canary grass, alfalfa, hybrid poplar and switchgrass have been proposed as future energy crops (Adler et al., 2007; Lewandowski et al., 2003). Reed canary grass (RCG – *Phalaris arundinacea* L.) is a potential bioenergy crop, and it is being increasingly cultivated on boreal organic soils, such as abandoned peat extraction sites. For example, the area under RCG in Finland during 2008 was about 19,000 ha and it is projected to increase to 100,000 ha by 2012. RCG can be used for burning when mixed together with peat and/or wood in thermal power stations (Flyktman and Salo, 2000). However, the atmospheric impact of this cultivation practice is unknown. Organic soils are considered to be risky soil types because of their potential for high emissions of N_2O (e.g. Mosier et al., 1996) and they have even been suggested to be banned from biomass production for bioenergy (OECD, 2007). Controlling of greenhouse gas balances of managed organic soils has proven to be difficult. They have been reported to emit large amounts of greenhouse gases into the atmosphere (Kasimir-Klemedtsson et al., 1997; Lohila et al., 2004; Maljanen et al., 2003a; Maljanen et al., 2004; Mäkiranta et al., 2007).

In spite of the fact that the cultivation area of reed canary grass is fast increasing, the atmospheric impact of the RCG cultivation is not yet well understood. The CO_2 balance of RCG cultivation measured using eddy covariance technique during a concurrent study at this site has been discussed in detail in Shurpali et al. (2009). The main objective of this study was to quantify the fluxes of non-CO_2 greenhouse gases from an abandoned peat extraction site cultivated with RCG. Secondly, these fluxes are compared with those from an adjacent bare peat site (BP site) under active peat extraction. For the purpose, the annual fluxes of N_2O and CH_4 from these two sites were measured for four years. In stark contrast to some recent observations (e.g. Crutzen et al., 2008), this study shows that there are organic soils where cultivation of perennial

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bioenergy crops is not hampered by high emissions of non-CO_2 greenhouse gases.

2. Methods

2.1. Study site

The study site, a 15-ha cutaway peatland with RCG cultivation, is located in the Linnansuo peatland complex in eastern Finland (62°30′N, 30°30′E) on the border of the southern and middle boreal climatic zones. Based on the 1971–2000 climatic normal, the mean annual temperature and precipitation of the region are 2.1 °C and 667 mm, respectively (Drebs et al., 2002). The coldest month is January (mean temperature, −10.6 °C) with July being the warmest one (16.0 °C). On average, a peak snow depth of 67 cm occurs in March and the mean duration of snow cover is 183 days.

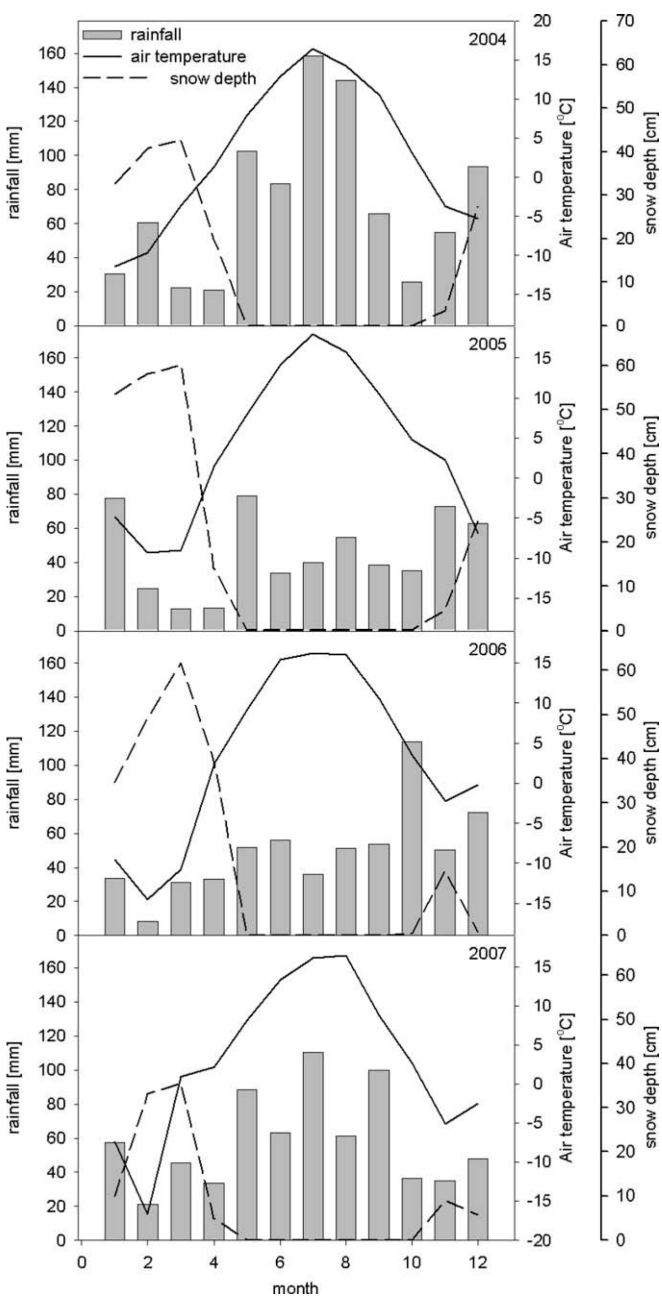

Fig. 1. Monthly patterns of air temperature, rainfall and snow depth at Linnansuo in eastern Finland during 2004–2007.

At this study site the years 2005 and 2006 were drier than 2004 and 2007, but average air temperatures did not differ significantly among the years (Fig. 1, Table 1). Here the duration of the growing season is defined according to the criteria described by the Finnish Meteorological Institute: the growing season starts (ends) when mean daily temperature rises above (goes below) 5 °C for five consecutive days. The long-term average length of the growing season in this region, based on the 30-year climatic data in 1971–2000, is 152 days, starting on May 6 and ending on October 5. During 2004–2007, the growing seasons varied from May 1 to October 17 (Table 1). All growing seasons were longer than the long-term average. The snow-covered season lasted 159, 148, 158 and 155 days and maximum snow depths were 48, 68, 76 and 49 cm in 2004, 2005, 2006 and 2007, respectively.

Drainage at the Linnansuo RCG site began in 1976, and extraction of peat for energy was initiated in 1978. The drainage ditches divide the cultivation area into 20 m wide strips. Originally, the ditches were 2 m deep and 1.2 m wide at the top. Peat extraction was stopped when the peat thickness varied from 20 to 85 cm. Cultivation of RCG (variety Palaton) started in 2001. In the beginning, the cultivation area was tilled, limed (finely-crushed dolomitic limestone [$CaMg(CO_2)_2$)]) at a rate of 7800 kg ha^{-1} and fertilized with NPK (17:4:13) fertilizer at a rate of 350 kg ha^{-1}. After sowing, the RCG crop was not harvested during the first three years. It was then harvested in the spring of the fourth year (2004) of the rotation and following this, annual harvesting commenced every spring after the snow melt (i.e. to dry the crop before the harvest, it was kept at the site over winter). The crop received a dose of NPK fertilizer (350 kg ha^{-1}) every season after harvesting. As RCG is being cultivated as a perennial crop, there is no annual tilling except at the time of land preparation (2001). In 2006, to increase soil pH, the RCG site received additional lime.

Adjacent to the RCG site, there is a site with bare peat soil and no vegetation cover (BP site). The BP site has a drainage history similar to that of the RCG site. The N_2O and CH_4 fluxes from this site were compared with the emission data from the RCG site. Peat is still being extracted from this site during summer months.

2.2. Supporting soil and meteorological measurements

Manually measured environmental variables were used to investigate the factors controlling N_2O and CH_4 emissions. These measurements, made at the same time as the chamber flux measurements (see Section 2.3), included air and chamber temperatures, soil temperature profile (0, 2, 5, 10, 15 and 20 cm depths) and soil moisture (at the 0–6 cm layer). At the RCG site water table depth and height of the vegetation were also measured. Temperatures were measured with a 20-cm long steel thermocouple probe (covered with a radiation shield during air temperature measurement) attached to an electronic thermometer. Soil moisture was measured with the ThetaProbe (Model: ML2x, Delta-T Devices Ltd., UK) attached to a moisture meter (type HH2). Groundwater wells were constructed adjacent to each location of flux measurement by inserting perforated plastic tubes into the soil to a depth of about 100 cm.

In the RCG site next to flux measurement plots there was also an automatic weather station (MAWS, Vaisala Ltd., Finland) equipped with air and soil temperature profile sensors. In the case of missing manual air temperature data during flux measurements, data from this weather station or the main instrument tower explained below were used.

Continuous meteorological and other environmental data were used to describe climatic conditions during the measurement years. Continuous data on air temperature (Model MP101A, Rotronic Instruments Ltd., UK) at 3.5 m height, snow depth (SR50A SonicRanging Sensor, Campbell Scientific, UK) and water