Soil greenhouse gas emissions from afforested cutaway peatlands

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Introduction

The most evident effect of afforestation of cutaway peatlands is the sequestration of atmospheric CO_2-C into the growing tree biomass. Changes in soil GHG fluxes are more difficult to predict. Documentation of the GHG-fluxes after afforestation is part of the national GHG inventory process [1]. In order to fulfill Finland's reporting needs on afforested organic soils, more information on soil GHG fluxes in peat cutaway areas is needed. The aim of this study was to produce estimates of the annual soil CO_2, CH_4 and N_2O emissions from typical afforested cutaway peatlands in Finland.

Material and methods

Afforested cutaway peatlands were located in the peat production area of Aitoneva, in Kihniö, central Finland. Six sites were selected to represent different tree species, developmental stages and soil characteristics (Table 1). On all of the sites peat harvesting ceased 15–20 years before afforestation. The mineral soil on the sites B39, B27 and P29 had been mixed into the peat during soil preparation. All the sites had been fertilized with K and P after afforestation.

The soil CO_2 effluxes were measured using a closed-chamber system with an external infrared gas analyser (EGM-4 CO_2 Analyzer). Measurements were done approximately weekly during the growing season and monthly during the winter from 2002 to 2005. The annual soil CO_2 effluxes were statistically modelled using continuously measured soil temperature as the driving variable [2]. For the winter season the average effluxes were used. During the snow-free periods the fluxes of CH_4 and N_2O were measured every 2–3 weeks using the static chamber method [3]. Annual flux rates were calculated as the sum of summer and winter season fluxes for each sample plot [2].

Table 1. Study site characteristics.

Site	Tree Species	Age year 2005	Stand volume, m3/ha	Peat depth, cm	Bulk density, g/dm3 0–20 cm	Ash content, % 0–20 cm	C/N ratio 0–20 cm
B39	Birch	39	141	16–17	0.202	19.6	23.8
B3-40	Birch	30–40	365	40–72	0.174	6.0	23.4
B27	Birch	27	86	55–77	0.570	79.3	23.3
P18	Pine	18	24	5–60	0.193	15.6	26.5
P43	Pine	43	248	38–55	0.173	6.4	24.5
P29	Pine	29	163	41–69	0.623	74.7	23.5

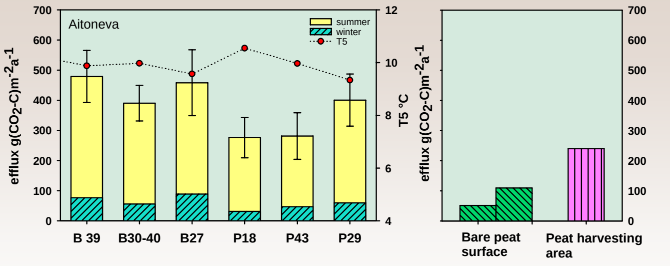

Fig. 1. Average annual soil CO_2 effluxes and standard deviations for the time period 7th June 2003 to 6th June 2004. Summer (May–October) and winter (November–April) fluxes from afforested cutaway peatlands are presented separately. The line depicts the average summertime soil temperature at 5 cm depth on cutaway peatlands. CO_2 emissions from bare peat surfaces in Aitoneva 20 years after abandonment [4] and from peat harvesting area in eastern Finland [5] are presented for comparison.

Results and discussion

Annual soil CO_2 effluxes in the studied sites varied from 275 to 479 g CO_2-C m^{-2} a^{-1} (mean 381±86 g C m^{-2} a^{-1}, Fig. 1). The proportion of the annual efflux emitted during the wintertime on all of the measured sites varied from 9% to 25%.

The soil CO_2 emissions on the afforested cutaway sites were clearly higher than the emissions from bare peat surfaces [4, 5] (Fig. 1). In contrast to bare peat surfaces, which had been void of vegetation for several years before CO_2 measurements, the afforested sites in this study have been vegetated for over 20 years before soil respiration measurements. Obviously the growing vegetation has produced fresh carbon as a substrate for heterotrophic microbes, thereby directly increasing the soil respiration rate and also through priming impacts on the decomposition rate of old peat. All afforested cutaway sites were fertilized in connection with the planting of tree seedlings on the sites. This increase in the peat nutrient content may have accelerated the microbial activity and the decomposition rate of the organic matter compared to non-afforested cutaway peatlands.

Assuming a tree growth of 46–329 g CO_2-C m^{-2} a^{-1} [6], the soil CO_2 efflux from afforested cutaway peatlands exceeds the carbon sequestration by tree growth and therefore these areas may act as sources of C into the atmosphere.

The average of the annual CH_4 fluxes was –0.04±0.02 g CH_4-C m^{-2} a^{-1} based on both the mean and median values meaning that afforested cutaway peatlands acted mainly as minor sinks of CH_4 (Fig. 2).

All of the studied sites emitted N_2O. Annual N_2O emissions varied from 0.01 to 0.48 g N_2O-N m^{-2} a^{-1}, the averages being 0.11 and 0.08 g N_2O-N m^{-2} a^{-1} for coniferous and deciduous forests, respectively. The emissions of N_2O during winter were, on average, 22% of the annual emissions. N_2O emissions from the cutaway sites were slightly higher than those reported from peat extraction areas [5]. This is probably a result of fertilization of the sites when planting trees and addition of tree litter containing organic C.

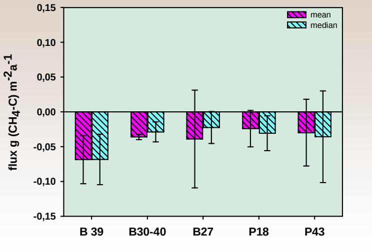

Fig. 2. Annual soil CH_4 fluxes presented as mean and median fluxes.

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