

Soil greenhouse gas emissions from afforested cutaway peatlands

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1. Introduction

From the total area of 1,200 000 ha of peatlands suitable for peat production in Finland (Virtanen and Hänninen 2004), annual peat harvesting area has been 42,000 – 59,000 ha during the last ten years. Peat harvesting has already ceased on more than 20,000 ha and by 2010 this area will have increased to 40,000 – 45,000 ha (Selin 1999). Forestry is considered to be the main after use option for cutaway peatlands (Selin 1999).

The most evident effect of afforestation is the sequestration of atmospheric CO₂-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 (GPG-LULUCF; IPCC 2003). 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 CO₂, CH₄ and N₂O emissions from typical afforested cutaway peatlands in Finland.

2. 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 potassium and phosphorus after afforestation.

On each study site, 2–8 sample plots (Table 1) for bare soil CO₂ efflux measurements were established in subjectively chosen locations to cover typical variation on the sites, no more than 150 m apart from each other. An aluminum tube with a diameter of 31.5 cm was inserted into the soil to a depth of 30 cm on each sample plot in order to exclude root respiration from the soil CO₂ efflux. The above-ground litter was removed from the sample plots and further accumulation of the fresh litter was prevented by placing a net above the sample plot. To eliminate autotrophic plant respiration, the above-ground parts of the green plants were removed by manual weeding and clipping at the beginning of the measurements. Measurements were done

approximately weekly during the growing season and monthly during the winter from 2002 to 2005.

The soil CO₂ effluxes were measured using a closed-chamber system with an external infrared gas analyser (IRGA) (EGM-4 CO₂ Analyzer). Soil temperatures at 5 cm depth were measured in the sample plot simultaneously with the chamber measurements. The annual soil CO₂ effluxes were statistically modelled using continuously measured soil temperature as the driving variable (Mäkiranta et al. 2006). For the winter season the average effluxes were used.

Table 1. Study site characteristics.

Site	Previous land use	Tree Species	Age year 2005	Stand volume, m ³ ha ⁻¹	Tree height, m	Peat depth, cm	Bulk density, g/dm ³	Ash content, %	C/N ratio	Number of sample plots	
										CO ₂	CH ₄ /N ₂ O
B39	Cutaway	Birch	39	141	21.9	16–17	0.202	19.6	23.8	2	-
B3-40	Cutaway	Birch	30–40	365	17.8	40–72	0.174	6.0	23.4	4	4
B27	Cutaway	Birch	27	86	11.3	55–77	0.570	79.3	23.3	4	3
P18	Cutaway	Pine	18	24	4.6	5–60	0.193	15.6	26.5	8	8
P43	Cutaway	Pine	43	248	16.0	38–55	0.173	6.4	24.5	4	4
P29	Cutaway	Pine	29	163	8.9	41–69	0.623	74.7	23.5	4	3

The fluxes of CH₄ and N₂O were measured from 3–8 sample plots (Table 1). Round collars with a diameter of 31.5 cm were used to delimit the permanent sample plots. During the snow-free periods the fluxes of CH₄ and N₂O were measured every 2–3 weeks using the static chamber method (Crill *et al.* 1988). Measurements and analyses have been reported in detail by Mäkiranta *et al.* (2006). Annual flux rates were calculated as the sum of summer and winter season fluxes for each sample plot separately in order to describe the spatial variations within the study sites (Mäkiranta *et al.* 2006).

3. Results and discussion

Annual soil CO₂ effluxes in the studied sites varied from 275 to 479 g CO₂-C m⁻² a⁻¹ (mean 381±86 g C m⁻² a⁻¹, Fig. 1). During the measurement period the average summertime soil temperature varied between the sites from 8.6 to 10.7 °C. The proportion of the annual efflux emitted during the wintertime on all of the measured sites varied from 9% to 25%.

The soil CO₂ emissions on the afforested cutaway sites were clearly higher than the emissions from bare peat surfaces in Aitoneva 20 years after abandonment (seasonal efflux being 52–110 g CO₂-C m⁻² a⁻¹ Tuittila *et al.* 1999) or from bare *Sphagnum* peat from a peat harvesting area in eastern Finland (annual efflux 240 g CO₂-C m⁻² a⁻¹ Nykänen *et al.* 1996). In contrast to bare peat surfaces, which had been void of vegetation for several years before CO₂ 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. At the beginning of the experiment the present above-ground litter was removed, but undoubtedly some fresh carbon remained in the old peat layer. 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 CO₂-C m⁻² a⁻¹ (Aro and Kaunisto 2003), the soil CO₂ 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.

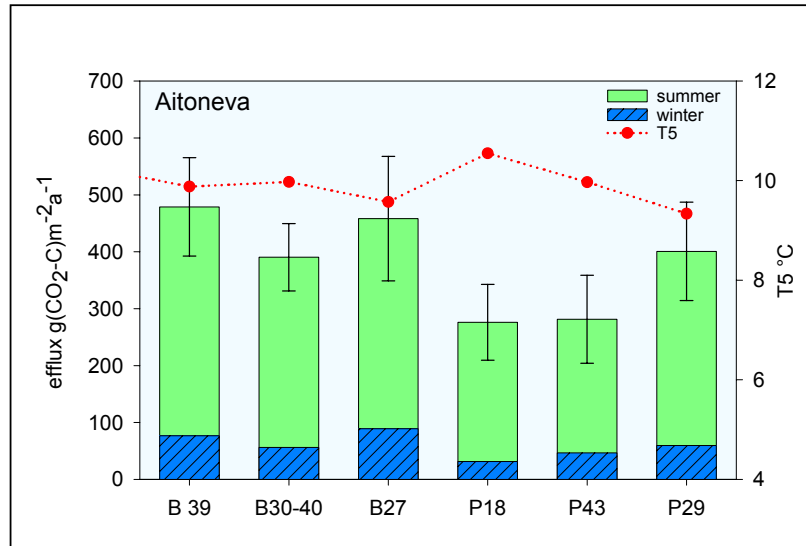


Figure 1. Average annual soil CO₂ effluxes and standard deviations for the time period 7th June 2003 to 6th June 2004. Summer (May–October) and winter (November–April) fluxes are presented separately. The line depicts the average summertime soil temperature at 5 cm depth. Redrawn from Mäkiranta *et al.* (2006).

The annual CH₄ fluxes on the sites varied from 0.07 to –0.02 g CH₄-C m⁻² a⁻¹. The average was –0.04±0.02 g CH₄-C m⁻² a⁻¹ based on both the mean and median values meaning that afforested cutaway peatlands acted mainly as minor sinks of CH₄.

All of the studied sites emitted N₂O. Annual N₂O emissions varied from 0.01 to 0.48 g N₂O-N m⁻² a⁻¹, the averages being 0.11 and 0.08 g N₂O-N m⁻² a⁻¹ for coniferous and deciduous forests, respectively. The emissions of N₂O during winter were, on average, 22% of the annual emissions. N₂O emissions from the cutaway sites were slightly higher than those reported from peat extraction areas (Nykänen *et al.* 1996). This is probably a result of fertilization of the sites when planting trees and addition of tree litter containing organic C.

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