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GREENHOUSE GAS BALANCE OF FORESTRY-DRAINED BOREAL PEATLANDS: SINKS OR SOURCES?

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SUMMARY

We estimated the current greenhouse gas balance (in CO_2 equivalents, CDE) for 68 forestry-drained sites in Finland, ranging from hemiboreal to north boreal vegetation zones and from fertile to poor sites. We found net emissions from soil at fertile but not at poor sites. The role of CH_4 and N_2O emissions was minor. The large CO_2 sinks of the growing tree stands caused the ecosystem balances to be clearly positive (sink) even at fertile sites.

KEY WORDS: forestry-drainage, boreal peatland, greenhouse gas balance

INTRODUCTION

Pristine boreal peatlands are sinks of atmospheric carbon dioxide (CO_2) as carbon is accumulated in the peat (Turunen et al., 2002). In the same time, methane (CH_4) is released (Waddington and Roulet, 2000). Nitrous oxide (N_2O) emissions are generally low, occurring mainly at fertile sites (Regina et al., 1996; Drewer et al., 2010; Lohila et al., 2010). As a consequence, pristine boreal peatlands have a long-term climate cooling effect (Frolking and Roulet, 2007).

Drainage of boreal peatlands for forestry may have both climate warming and climate cooling impacts on the greenhouse gas (GHG) balance: When ground water table is lowered, CH_4 emissions decrease or even cease (Ojanen et al., 2010). If the peat layer starts to degrade, as is the case after drainage for agriculture (Maljanen et al., 2007), peatland turns into a source of CO_2. In forestry-drained peatlands N_2O emissions are generally low, but substantial emissions may occur at fertile sites (Ojanen et al., 2010). If drainage is successful, tree stand biomass starts to increase, which results in a considerable CO_2 sink (Tomppo, 1999; Minkkinen et al., 2001).

There is widely data on tree growth and CO_2, CH_4 and N_2O fluxes in forestry-drained boreal peatlands (Ojanen et al. 2010; Statistics Finland, 2011; Swedish Environmental Protection Agency, 2011). On the other hand, very little data exists on net CO_2 exchange (Hargreaves et al., 2003; Lohila et al., 2011) and soil C stock changes after drainage (Minkkinen and Laine, 1998; Minkkinen et al., 1999; Laiho et al., 2008). Also, studies estimating the current balance of all the three GHGs at the same sites, thus empirically testing if the sites are GHG sinks or sources, are lacking.

In this study we estimated the CO_2, CH_4, and N_2O balances for 68 peatland sites in Finland, by measuring the soil–atmosphere fluxes of GHGs and estimating net primary production and litter production for each site.

MATERIAL AND METHODS

The 68 study sites were located in all parts of Finland except for the northernmost part where drainage for forestry is scarce (Ojanen et al., 2010). Sites on different drained peatland site types (Vasander and Laine, 2008) were equally included to represent the continuum from the most fertile *Herb-rich type* via *Vaccinium myrtillus type* and *Vaccinium vitis-idaea type* to the poor *Dwarf shrub type*.

GHG balance was defined as the sum of the ecosystem–atmosphere net fluxes of CO_2, N_2O, and CH_4, as converted to CO_2 equivalents (CDE). For CH_4 and N_2O, net fluxes were those annual soil–atmosphere fluxes estimated by Ojanen et al. (2010). The CDEs for N_2O and CH_4 were calculated by multiplying their net fluxes by their global warming potentials (GWP_{100}): 25 for CH_2 and 298 for N_2O (IPCC 2007). For CO_2, the balance consisted of soil–atmosphere net flux and the CO_2 sink of the growing tree stand (Ojanen et al., manuscript).

The soil–atmosphere net flux of CO_2 was defined as litter production (L) – aerobic decomposition (D). L was estimated following the procedures presented by Laiho et al. (2003). D was estimated as the sum of measured heterotrophic soil respiration (Ojanen et al. 2010) and modelled decomposition of the litter layer. Tree stand CO_2 sink was estimated as the difference in living tree biomass between two consecutive estimations. Positive values indicate sinks and negative values sources of GHG.

RESULTS

There was a clear distinction between the soil CO_2 balance of the fertile and the poor sites (Fig. 1). The poor sites were on average a small sink of CO_2, the fertile sites a source. The source at the fertile sites increased as the temperature sum increased. The CO_2 sink of the growing tree stand increased from poor to fertile sites and from north to south

Both fertile and poor sites were, on average, GHG sinks when the tree stands were included (Fig. 2). The negative soil balance of the fertile sites, when compared to the positive soil balance of the poor sites, was more than compensated for by the larger CO_2 sink of the tree stand. The effect of CH_4 and N_2O on the ecosystem balance was small.

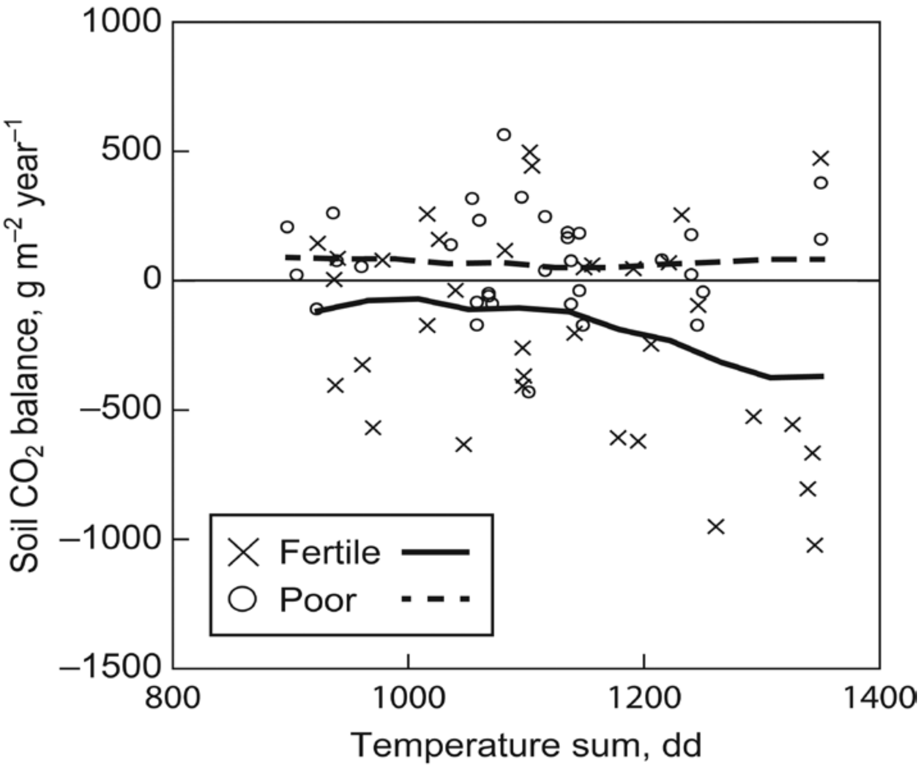

Figure 1. Soil CO_2 balance of the study sites. Poor sites are those classified as *Vaccinium vitis-idaea type* or *Dwarf shrub type*; fertile sites are those classified as *Herb rich type* or *Vaccinium myrtillus type*. Lines depict the running averages. Positive value indicates sink and negative value indicates source.

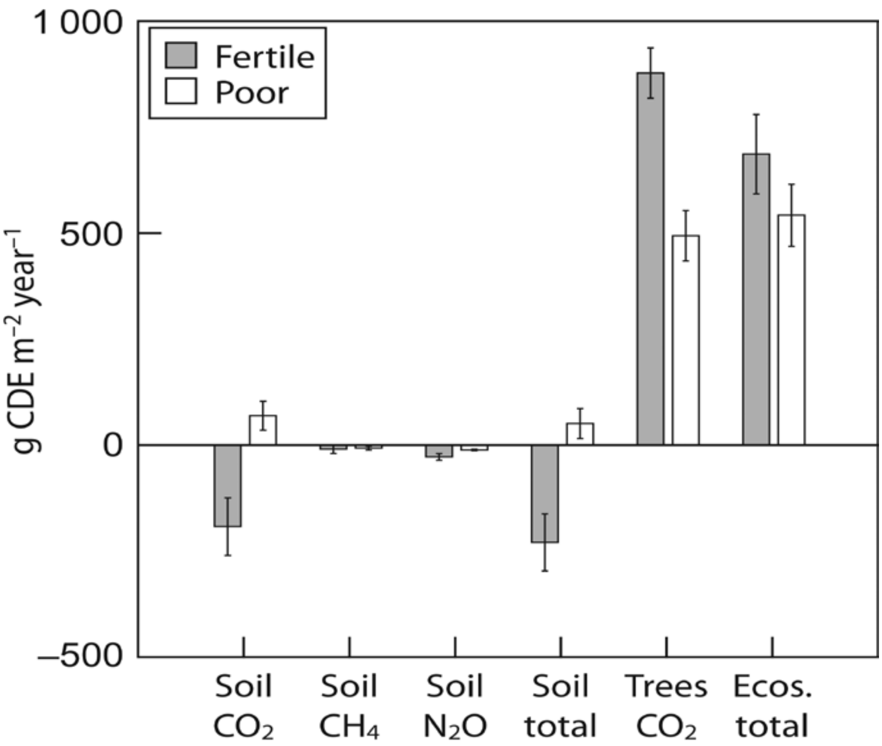

Figure 2. Average ecosystem greenhouse gas balance (in CO_2 equivalents, CDE) of the study sites. The balance is calculated as the sum of the balances of CO_2, CH_4 and N_2O. Poor sites are those classified as *Vaccinium vitis-idaea type* or *Dwarf shrub type*; fertile sites are those classified as *Herb rich type* or *Vaccinium myrtillus type*. Positive value indicates sink and negative value indicates source.

DISCUSSION

The results of this study confirm the earlier findings (Minkkinen and Laine, 1998; Minkkinen et al., 1999; Lohila et al., 2011) in that peat accumulation at nutrient poor boreal peatlands may continue even after drainage for forestry. Thus, climatically sustainable ditching-based forestry seems to be possible on nutrient-poor peatlands. On the other hand, fertile peatland soils turn into CO_2 sources after drainage.

Although the current ecosystem GHG sink of the fertile sites was even higher than that of the poor sites, forestry is unlikely to remain sustainable in the long-term, as the positive balance depends on the growing tree stand biomass. Only if the harvested biomass is later stored, for example in wooden buildings or as bio char in agricultural soils, the current high sink of the growing tree stand could be seen as a means to mitigate the climate change.

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