Extended abstract No. 329

# FIRST RESULTS OF $CH_4$ MEASUREMENTS FROM PRISTINE, DRAINED AND RESTORED SPRUCE SWAMP FORESTS IN SOUTHERN FINLAND

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## SUMMARY

CH4 emissions were measured using a closed-chamber discrete sampling technique during the summer and autumn 2011 on pristine, drained and restored meso- and meso-eutrophic spruce swamp forests in the south boreal vegetation zone in Finland. First results indicate that contrary to expectations, draining of a spruce swamp forest does not affect $CH_4$ emissions. Intra-site differences were greater than inter-site differences, with largest emissions measured from ditches on the drained and restored sites and from the mire edges on the pristine sites.

KEY WORDS: drainage, restoration, rewetting, soil microbial activity, spruce swamp forests

## INTRODUCTION

Pristine peatlands are generally considered a major source of the greenhouse gas methane ($CH_4$) (Blodau, 2002). Methane production and consumption in peatlands are controlled by a dynamic combination of the water table level, soil temperature, site fertility and vegetation. Methane is produced as the end product of anaerobic decomposition processes by methanogens and consumed in oxic conditions by methanotrophs (Yrjälä *et al.* 2011); therefore water table level controls the thickness of the layer in which methanotrophs can function and consume methane. When the water table is near the soil surface, soil temperature becomes an important factor by controlling how rapid the methane-producing anaerobic reactions are (Leppälä *et al.* 2011). Site fertility affects primary production and controls the type of litter is available for decomposers (Straková *et al.* 2010, Turetsky *et al.* 2010), while the aerenchymic tissues of certain vascular plant species provide a pathway for methane to escape from the soil bypassing the oxic peat layer and the methanotrophs altogether on one hand and feed substrates directly into the anoxic peat layer for the methanogens to consume on the other (Joabsson *et al.* 1999). Thus the highest methane emissions in the boreal zone are generally found on sedge-dominated mesotrophic fens with a shallow water table and the lowest on tree-dominated sites with a deep water table (Huttunen *et al.* 2003). However, due to the complex nature of the environmental controls, the emissions can be highly variable both temporally and spatially.

Peatland drainage lowers the water table and thus increases the space favourable to methane oxidation; on most sites $CH_4$ emissions are much reduced after draining (Yrjälä *et al.* 2011), except for the ditches, which may become a significant $CH_4$ source (Minkkinen & Laine 2006). Drainage for forestry has detrimental effects on the quality of the water draining from the peatland (Vuori *et al.* 1998) and as it alters the vegetational composition of the ecosystem to represent an upland forest ecosystem (Laine *et al.* 1995). Thus watercourses and the landscape diversity are negatively affected by peatland drainage.

Because of the scale at which peatlands have been drained for forestry in Finland and elsewhere in the boreal region, measures have been taken to restore some of these sites. Especially important would be to restore spruce mires, or spruce swamp forests, that have been among the most intensively drained peatland types. While half of the peatland area in Finland has been drained, mostly for forestry purposes (Hökkä *et al.* 2002), up to 80% of spruce mires have been drained. Commonly the method of mire restoration drained for forestry is to raise the water table level by filling in and damming the ditches and by removing some or the entire forest stand. In spruce swamp forest restoration the site is left as forested and dead wood is commonly created.

Little is known about $CH_4$ emissions from spruce swamp forests and knowledge on the emissions from their restored state is completely lacking. Spruce swamp forests usually have large drainage basins and thus potentially high water tables. However, this water table is mostly moving, oxygenated water, which could support activity of methanotrophic microbes. The surface vegetation can be quite diverse, with several *Sphagnum* and other bryophyte species mixed with *Care*x species in the wet end of the spruce mire spectrum and forest dwarf shrubs in the dry end. In this paper we present the first results of $CH_4$ flux measurements made on spruce swamp forests in their pristine, drained and restored stage.

## MATERIAL AND METHODS

We selected seven spruce swamp forests in Southern Finland for the study. Two of these were pristine, two drained for forestry and three were restored sites. All the sites except one, were mesotrophic, characterised by *Vaccinium myrtillus,Carex globularis, Trientalis europea* and *Sphagnum girgensohnii* in their pristine stage. One restored site was meso-eutropic with less dwarf shrubs and more herbaceous species. On each site, four sample plots were selected for measurements and boardwalks were built adjacent to them in early summer to minimise the disturbance during measurements. The plots were placed perpendicular to the ditches or the mire's edge so that on the drained and restored sites one was in the ditch, one was adjacent to the ditch on the dug-out peat and two were on the strip between ditches. On the pristine sites the plots were placed about 10 metres apart from each other, inwards from the mire edge. The vegetation on the measuring plots was left untouched. A 2-cm deep groove was fixed into the surface peat to ensure an airtight fit of the gas sampling chamber during measurements. On each site there were three wells near the measurement plots for water table level measurement.

We applied round closed chambers (d=31,5 cm, h=30 cm) for gas flux measurements. A fan was placed in the roof of the chamber to prevent atmosphere stratification inside the chamber. During the 35 minutes closure time samples were taken at 5, 15, 25 and 35 minutes after the closure. Samples of 20 ml were taken through a plastic hose closed with a 3-way tap with a syringe. Before taking the actual sample, the hose was flushed by pulling air through it with the syringe and pushing it back into the chamber. After sampling the tap was closed and the sample was pushed into a vacuum-containing 12-ml glass vial. Temperature readings were done before sampling at 5-cm depth at the centre of the sampling plot and mid-sampling from the air inside the chamber. Ambient air temperature was measured twice, before sampling the first plot and after sampling the last plot. We started the sampling started at mid-summer and continued till the autumn.

The $CH_4$ concentration in the gas samples were analysed at the Central laboratory of the Finnish Forest Research Institute, Vantaa. The analyses were done with an Agilent 6890N gas chromatograph (GC), using flame ionisation (for CH4) detector. After analysis, the results were manually filtered to see if there had been some disturbances during the sampling, such as methane bubbling in the sampling plot, or the chamber tilting mid-sampling and the atmosphere inside being diluted with ambient air. If the disturbance happened only before the last sample, and the first three samples appeared reliable, e.g. a linear fit pointed to a sensible initial $CH_4$ concentration, only the last value was removed. Otherwise the whole measurement was discarded. 20% of the measurements showed signs of bubbling before the last sample and were discarded.

$CH_4$ flux was calculated using a linear fit over time. Because the so far exciting data was insufficient to analyse the dependence of the $CH_4$ flux on temperature and water table, they are not shown in this paper. Instead, a preliminary scale of emissions and a comparison between the pristine, drained and restored sites is presented.

## RESULTS AND DISCUSSION

All results are presented in mg $m^{-2}$ $day^{-1}$.The results are from single samplings from all three restored sites and one of the pristine and drained sites, and three samplings from one of the drained and pristine sites.

Table 1. Measured $CH_4$ fluxes from two pristine, drained and restored spruce swamp forests in Southern Finland. Positive values indicate emission from the site and negative net flux into the ecosystem. All the sites are mesotrophic except Mustakorpi which is meso-eutrophic.

| Site | mean | sd | n |
|---|---|---|---|
| Susimäki PRISTINE | 1,3 | 2,9 | 7 |
| Evo PRISTINE | 0,8 | 1,0 | 4 |
| Vesijako DRAINED | 1,6 | 0,3 | 4 |
| Konilampi DRAINED | 0,5 | 1,3 | 12 |
| Mustakorpi RESTORED | -0,8 | 4,1 | 2 |
| Evo RESTORED | 8,6 | 16,5 | 4 |
| Soukonkorpi RESTORED | 0,6 | 3,1 | 2 |

Table 2. $CH_4$ fluxes by treatment

| Treatment | mean | Mean without outlier |
|---|---|---|
| PRISTINE | 1,1 | |
| DRAINED | 1,0 | |
| RESTORED | 2,8 | -1,1 |

The results show that the $CH_4$ dynamics of spruce mires are complicated: at a given time, the same site can apparently act as a methane sink on one location and as a source on another (Table 1.). Against the paradigm, the drainage hadn’t decreased emissions in comparison to pristine, probably because the emissions from the pristine sites were low. There were differences between the sites based on whether or not they were restored: the highest emissions were measured on the restored sites, although if a single ditch plot on the Evo RESTORED site with the highest emission of 42 mg $m^{-2}$ $day^{-1}$, a clear outlier, is left out, the restored sites acted as $CH_4$ sinks (Table 2.).

Table 3. $CH_4$ fluxes by sampling location within a site.

| Plot | Pristine | Drained | Restored | Restored without outlier |
|---|---|---|---|---|
| Ditch/edge | 1,3 | 2,2 | 22,7 | 3,7 |
| Beside ditch | 0,8 | 1,0 | -4,9 | |
| Mid-mire | 1,1 | -0,5 | -1,0 | |

Both the measured emissions and absorption of $CH_4$ were in the scale of 1-2 mg $CH_4$ $m^{-2}$ $d^{-1}$. The ditch plots on the drained and restored sites, or the mire edges on the pristine sites, had the highest emissions (Table 3.), and the plots beside the ditches or mid-mire had the lowest emissions and occasionally even acted as $CH_4$ sinks. The difference between the ditches and the other habitats in methane emission agrees well with the results of Minkkinen & Laine (2006) and shows their special quality within ecosystem similarly to Kangas et al. (2012 in this compilation) and Maanavilja et al. (2012 in this compilation).

Comparing to other studies, the pristine sites show emissions well within the mean and standard deviation, 0.7 and 2.9 mg $m^{-2}$ $d^{-1}$, for daily emissions from spruce swamp forests observed by Huttunen *et al.* (2003) but are smaller than those from meso-eutrophic spruce swamp forests (seasonal average 3.5–12 mg $m^{-2}$ $d^{-1}$) reported by Minkkinen et al. (2007).

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