Suo 43(4–5): 237–240, 1992(1993)

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# THE EFFECT OF CHANGING WATER TABLE ON METHANE FLUXES AT TWO FINNISH MIRE SITES

Martikainen, P.J., Nykänen, H., Crill, P. & Silvola, J. 1992: The effect of changing water table on methane fluxes at two Finnish mire sites. — Suo 43:237–240. Helsinki. ISSN 0039-5471

Methane fluxes were measured using a static chamber technique on a minerotrophic fen and an ombrotrophic peat bog site located on the Lakkasuo mire complex in central Finland. Both sites consisted of a virgin area and an area drained in 1961 by ditching. The measurements in 1991 were made biweekly from spring thaw to winter freezing. During this period, the mean $CH_4$ emission from the virgin minerotrophic site and virgin ombrotrophic site was 98 mg $m^{-2}d^{-1}$ and 40 mg $m^{-2}d^{-1}$, respectively. The mean emission of $CH_4$ from the drained ombrotrophic site was 18 mg $m^{-2}d^{-1}$. The drained minerotrophic site consumed methane during most of the measuring period, the average uptake was 0.13 mg $m^{-2}d^{-1}$. Draining had lowered the average water table by 4 cm at the ombrotrophic site and by 20 cm at minerotrophic site. The possible reasons for the different development of the water table and methane fluxes at ombrotrophic and minerotrophic sites after draining are discussed.

Keywords: Drainage, methane flux, methane oxidation, nutrient status, peat soil

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## INTRODUCTION

The concentration of methane in the atmosphere is increasing by 1% $yr^{-1}$ (Cicerone & Oremland 1988, Khalil et al. 1989). Wetlands of northern hemisphere produce 6–16% of all methane produced in the world (Matthews & Fung 1987, Anselman & Crutzen 1989). Increasing air and soil temperatures favours methane emissions (Crill et al. 1988, Khalil & Rasmussen 1989, Pulliam & Meyer 1992). However, it has been suggested that the climatic change will lower water tables in northern latitudes (Roulet et al. 1992a), which would be expected to affect methane fluxes (Oremland & Culbertson 1992). We studied the changes in methane fluxes after artificial draining at two Finnish mires. The conditions in drainages may reflect the future conditions with respect to water table and vegetation development.

## MATERIAL AND METHODS

The two sites examined were located on the Lakkasuo mire complex in Finland (61°47´N, 24°18´E). The sites differ in their nutrient status. The first site is a minerotrophic sedge fen and the second an ombrotrophic cottongrass pine bog. The sites consist of both a virgin area and an area drained for forestry by ditching in 1961. The drained minerotrophic site was fertilized with phosphorus (53 kg $ha^{-1}$) and potassium (63 kg $ha^{-1}$) in 1984. The ombrotrophic site has never been treated with fertilizers. At the minerotrophic site, the ditching has resulted in a succession towards a very different system from the original one. Typical fen species (*Sphagnum fallax, S. papillosum, Carex lasiocarpa, C. rostrata*) on the virgin area have been replaced by spruce swamp and forest species (e.g. *Polytrichum commune*). While on the virgin area there are only a few and small scattered Scots pines, the stand volume on the drained area was about 115 $m^3$ $ha^{-1}$ (*Pinus sylvestris*, 99%, and *Betula pendula* and *B. pubescens*, 1%). At the ombrotrophic site, the effect of ditching has been only small. However, slight changes from typical lawn species (*Sphagnum angustifolium, Eriophorum vaginatum*) has taken place towards hummock species (*Sphagnum fuscum, Pleurozium shreberi*). No effect of ditching can been seen in the growth of trees; the tree stand (*Pinus sylvestris*) was 50 $m^3ha^{-1}$ both in the virgin and drained area. Depth of the peat layer was 1.5 m at the minerotrophic site and 2.6 m at the ombrotrophic site (Laine et al. 1986, 1992).

Gas fluxes were measured every second week from spring thaw (April 24) to winter freeze (December 12) in 1991. A closed chamber method was used for the flux measurements (Crill et al. 1988). The chamber covered an area of 0.36 $m^2$ and the volume of chamber was 60 L. Two chamber collars were inserted into peat at all areas in September 1990 and one additional collar in October 1991. The study sites were equipped with broadwalks to prevent disturbance of peat during sample collection.

Gas samples for flux measurements were collected using 50-ml polypropylene syringes equipped with 3-way stopcocks. Four gas samples were collected during the measuring period of 30 min. At the time of gas sampling chamber temperature, temperature in peat profiles (0–30 cm), and water table near the chambers were measured. Gas concentrations in syringes were analyzed within 24 hours of collection. The leakage of methane (about 2.5%) from the syringes during the storage was taken into account when calculating the fluxes. This diffusion correction was made by a regression model constructed experimentally (results not shown).

In the laboratory, methane concentrations were analyzed with a HP 5890 Series II gas chromatograph with a flame ionization detector. The column was Haysep-Q (80/100 mesh 4 m by 3 mm) which was kept at 40°C. Helium was used as a carrier gas at flow rate of 40 mL $min^{-1}$. Detector temperature was 200°C. Injection of gas samples was made by a 0.5 ml loop in a 10-port valve. Compressed air, calibrated with 9.71 ± 0.29 ppm $CH_4$ in nitrogen (AGA, Germany), was used to calibrate the gas chromatograph. The coefficient of variation for the methane standard measurements was below 0.6%. Fluxes were determined by calculating the linear increase or decrease in the methane concentration during the measuring period of 30 minutes.

## RESULTS

During the measurements, air temperature ranged from –2.5°C to 24.7°C at the minerotrophic site and from 0°C to 26.7°C at the ombrotrophic site. The average water table at the virgin and drained area of the minerotrophic site was 2.7 and 22.5 cm below the peat surface, respectively. At the ombrotrophic site the average water table at the virgin area was 6.4 cm and 10.5 cm at the drained site.

The rate of methane emission at the virgin areas at the both mires was favored by high soil temperatures (Fig 1a–d). The average flux at the virgin area of the minerotrophic site in 1991 was 98 mg $CH_4$ $m^{-2}d^{-1}$ and 40 mg $m^{-2}d^{-1}$ at the virgin area of the ombrotrophic site. There was some $CH_4$ emission at the drained area of the minerotrophic site only when the soil temperature was low and the water table was high. During the summer this peat consumed $CH_4$ (Fig. 1e). The average uptake for the whole study period was 0.13 mg $CH_4$ $m^{-2}d^{-1}$. Also at the drained area of the ombrotrophic site, the methane emissions (average 18 mg $m^{-2}d^{-1}$) were lower than those at virgin area (average 40 mg $m^{-2}d^{-1}$). However, there was always some methane emission at the drained area (Fig. 1g).

## DISCUSSION

The decrease in the water table after draining has been higher at the minerotrophic site than at the ombrotrophic site, although the depth of the ditching has been the same at both sites. This difference in the water table obviously explains the differences in the methane fluxes at the drained sites. There might be several reasons for the different development of water table at the drained ombrotrophic and minerotrophic sites. Firstly, the hydraulic conductivity for the drained *Sphagnum* peat of the ombrotrophic site is lower than that for the drained sedge and woody peat of the

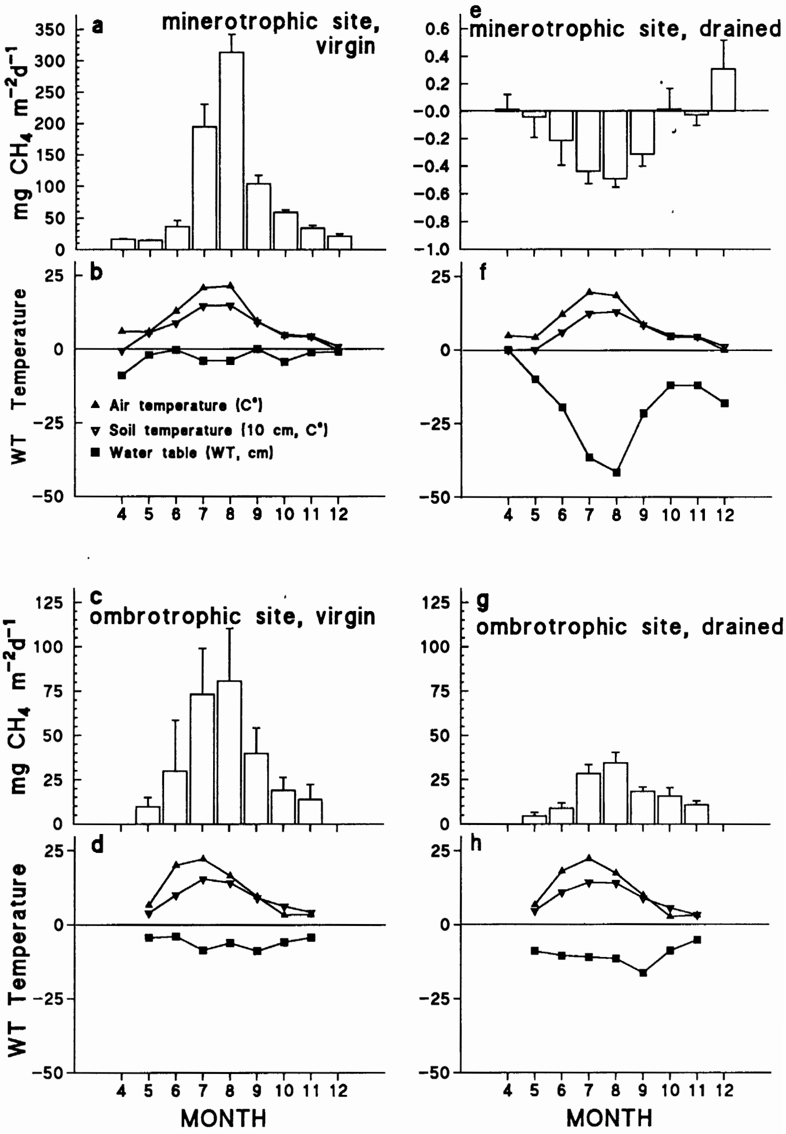

Fig. 1. Methane fluxes (monthly average and S.E), air temperature, soil temperature and water table of the minerotrophic fen (a, b, e, f) and ombrotrophic bog (c, d, g, h) sites at Lakkasuo mire complex. Symbols used are explained in b.

minerotrophic site (Päivänen 1973). Secondly, the drained minerotrophic site had higher tree stand growth because of better nutrient status (Laine & Vanha–Majamaa 1992). Therefore, the evapotranspiration from the drained minerotrophic site could be higher than that from the drained ombrotrophic site where the stand development was poor. Thirdly, the peat of the drained minerotrophic site had higher humification degree and lower pore volume than those in the peat of the drained ombrotrophic site. At a certain evapotranspiration level the water table could lower more in the minerotrophic peat than in the ombrotrophic peat.

Methane emissions from virgin minerotrophic site (fen) range in previous measurements from 3 to 360 mg $m^{-2}d^{-1}$ and emissions from ombrotrophic sites (bogs) have been reported to be from 6 to 93 mg $m^{-2}d^{-1}$ (Crill et al. 1991, Roulet et al. 1992b). Also in the present work methane emissions at the more fertile virgin site exceeded that at the nutrient poor virgin site. A small additional decrease (average 4 cm, range from 1 to 9 cm) in water table because of the ditching reduced the methane emission at the ombrotrophic site. However, there never was net methane uptake at the drained ombrotrophic site as there was at the drained minerotrophic site. The lower water table at the drained minerotrophic site could favor methane oxidation which would be a reason for the difference in methane fluxes between these two sites. Lien et al. (1992) studied the methane oxidation potential of peat samples taken from the peat profiles of the present sites. They found that the methane oxidation potential was higher in the samples of the drained ombrotrophic site than that in the samples of the minerotrophic site. On the other hand, the aerated profile was much deeper at the drained minerotrophic site than that at the drained ombrotrophic site. The integrated methane oxidation in the aerobic peat profile of the drained minerotrophic site could thus be high enough to oxidize all the methane diffused from the anaerobic zone. However, when the soil temperature was low in early spring and late autumn methane oxidation in the upper profile could not eliminate all the methane evolved from the lower anaerobic zone.

The climatic change may lower water tables in northern peatlands (Roulet et al. 1992a). The hydrological conditions at the drained mires may have similar characteristics as found in the future at virgin mires. The development of the water table will greatly affect the methane emissions from northern mires. The changes of the vegetation associated with nutrient status of mires may further regulate the fluxes by influencing the water table via evapotranspiration.

## ACKNOWLEDGEMENTS

We thank Jukka Alm for botanical data and Tapani Sallantaus for useful suggestions about the manuscript. This work was supported by the Academy of Finland, National Public Health Institute and University of Joensuu.

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