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WINTER GREENHOUSE GAS EMISSIONS OF A MINEROTROPHIC FEN UNDER NATURE CONSERVATION MANAGEMENT IN NORTH-EAST GERMANY

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SUMMARY

Drained peatlands are sources of carbon dioxide (CO_2) and nitrous oxide (N_2O). While CO_2 emissions mainly occur in summer, high N_2O emissions may also occur in winter. Abandonment of intensive grassland possibly leads to low nutrient supply and thus to low N_2O emissions. Here we examine the role of extensification practices on greenhouse gas (GHG) emissions from a temperate drained fen in winter. Although the studied winter was extraordinarily cold, CO_2 and N_2O emissions were 4.4 t ha^{-1} and 2.6 t ha^{-1} CO_2-equivalents, whilst methane (CH_4) emissions were negligible. Thus extensification of grassland use alone may not be a suitable measure to reduce GHG emissions from temperate drained fens.

KEY WORDS: Peatland, nitrous oxide, carbon dioxide, extensive grassland, non-growing season

INTRODUCTION

Peatlands are an important element of the global GHG cycles (Frolking *et al.* 2006). Natural peatlands are regarded as long-term sinks of C and N, while emitting significant amounts of CH_4. In contrast, drained peatlands are a source for CO_2 and N_2O due to peat decomposition with CO_2 fluxes up to 50 t ha^{-1} a^{-1} and N_2O fluxes up to 60 kg ha^{-1} a^{-1} (Couwenberg *et al.* 2011). Drained eutrophic fens have a higher potential of emitting N_2O than virgin fens or drained but nutrient-poor fens (Regina *et al.* 1996). Although annual release of N_2O can be extremely erratic (Flessa *et al.* 1995), it is shown that non-growing-season fluxes may contribute 40-80 % to the annual emission (Flessa *et al.* 1995, Maljanen *et al.* 2009). However, studies from temperate peatlands on winter N_2O emissions are scarce (Beek *et al.* 2010, Hendriks *et al.* 2007). In addition, abandonment of intensive grassland use seems to lower N_2O emissions due to the lack of mineral fertiliser (Hendriks *et al.* 2007). Therefore we investigated winter GHG fluxes on a drained temperate fen that is under extensive agricultural use following nature conservation management guidelines. Since cool temperatures lower microbial metabolism we expect both CO_2 and CH_4 fluxes to be low. Because land use abandonment possibly reduces N_2O emissions (Hendriks *et al.* 2007) we also assume N_2O fluxes to be low.

MATERIAL AND METHODS

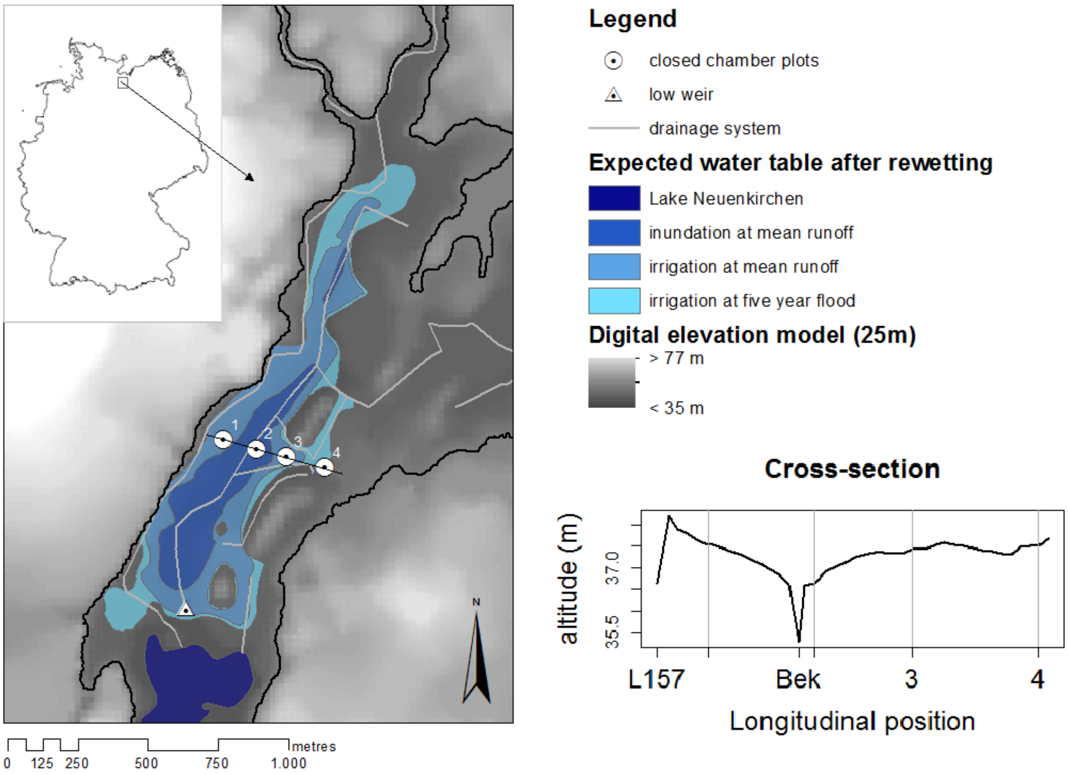

Figure 1. Map of the study site “Neuenkirchener Niederung” showing measurement plots, the drainage system, expected water conditions after rewetting, and landscape topography. The inset shows the location in north-east Germany.

The study site (53°36’ N, 10°59’ E) is part of a small river valley (“Neuenkirchener Niederung”) in north-east Germany (Fig. 1). Mean annual air temperature is 9.0 °C, mean air temperature in January is 0.2 °C and average snow cover endures 5.9 days. Annual sum of precipitation is 711 mm with a climatic water balance of +134 mm. The study site originally represents a percolation mire. However, deep drainage ditches (1.5 – 2.2 m) have altered the water balance of the system profoundly. From the 1970s until 2004, the fen was intensively used as grassland. Since then, it has been managed under nature conservation guidelines, such as abandonment of mineral fertiliser, reduced cutting frequency and a cattle-free winter period. Plant-species of intensive grassland use are still dominant (e.g. *Alopecurus pratensis* L., and *Poa trivialis* L.). Peat thickness reaches more than 5 m, with the upper layer of peat (1 m) being strongly decomposed (H8 – H10, von-Post scale). A rewetting of the fen is planned but not yet implemented.

In October 2009, four plots with three measurement spots each were established following a transect crossing the “Neuenkirchener Niederung” from the west to the east (Fig. 1). The plots were chosen according to expected water conditions after a planned rewetting of the mire. At each spot circular PVC collars were inserted to a depth between 5 and 10cm. GHG fluxes were estimated from concentration measurements using the non-steady-state chamber method. Sampling was carried out biweekly from November 2009 until March 2010. For each sampling, opaque PVC-chambers (d = 30 cm, h = 30cm) were carefully placed on top of the collars. Snow within the collar was not removed. Four gas samples were taken every 15 minutes with evacuated gas flasks (100 ml). The samples were analysed for concentration of CO_2, CH_4, and N_2O by a gas chromatograph (Perkin Elmer Auto System) using an Electron Capture Detector (ECD) and a Flame Ionization Detector (FID). The precision of analyses was about 10 ppb for CH_4, 70 ppb for N_2O and 10 ppm for CO_2. Furthermore, we measured depth of water table, soil and air temperature during each sampling campaign. High resolution meteorological data were collected by a weather station seven km SE of the study site.

Gas flux rates were estimated from the chamber concentration data using the R-package “flux” (Jurasinski and Koebsch 2011). Flux models with $R^2 \geqq 0.8$ were discarded. Plot-wise fluxes are calculated as mean fluxes of three replicates. Total emissions were estimated by integrating the area under the flux curves. Differences of fluxes and environmental parameters between the plots were tested with the pair-wise Wilcoxon-rank-test with Bonferroni adjustment.

RESULTS

The winter 2009/2010 was the most unusual for 30 years in north-east Germany. The mean temperatures of Dec, Jan and Feb fell 1.6 to 4.4 °C below the long-term mean temperatures (1970-2000). The average snow cover of 6 days was exceeded by more than 60 days lasting from late December 2009 until the beginning of March 2010. Maximum thickness of snow cover reached 40 cm at the end of January 2010. During this period, soil temperature remained constantly around 0 °C, although air temperature fell as low as -17 °C. In contrast, a week-long freeze-thaw cycle occurred after snow melting in March 2010, with the topsoil freezing and thawing daily. Depth of water table slightly differed among the four plots according to the expected hydrological range. At Plot 2, depth of water table was significantly lower than at Plot 4 ($p < 0.05$). Plot 1 and 3 neither differed significantly ($p < 0.05$) from each other nor from Plot 2 and 4. In addition, parts of the fen (Plot 2, similar to “inundation at mean runoff”, Fig.1) were inundated by melting water for two weeks from the beginning March 2010.

GHG fluxes occurred during the whole measurement period, also when the ground was covered with snow (Fig. 2). The highest flux rates of CO_2 and N_2O were recorded in November and March, when the highest temperatures and no snow cover were recorded. CO_2 fluxes were similar at all 4 plots reaching a maximum of 650 mg m^{-2} h^{-1}. CH_4 fluxes were near zero throughout the study period except at Plot 1 and 2 in November and after snow melting in March (up to 490 µg m^{-2} h^{-1}). N_2O fluxes reached values up to 420 µg m^{-2} h^{-1}at Plots 1-3. Significant higher fluxes ($p < 0.05$) were recorded at Plot 4 (up to 1,900 µg m^{-2} h^{-1}). On March 10th an N_2O flux rate peak was observed at Plot 4 (1,400 µg m^{-2} h^{-1}) following a week-long freeze-thaw cycle. Overall, CO_2, CH_4 and N_2O fluxes contributed 63 %, 0.2 % and 37 % to the GHG emissions of the study site, respectively. On average, the study site emitted 7.0 t ha^{-1} CO_2-equivalents during the study period.

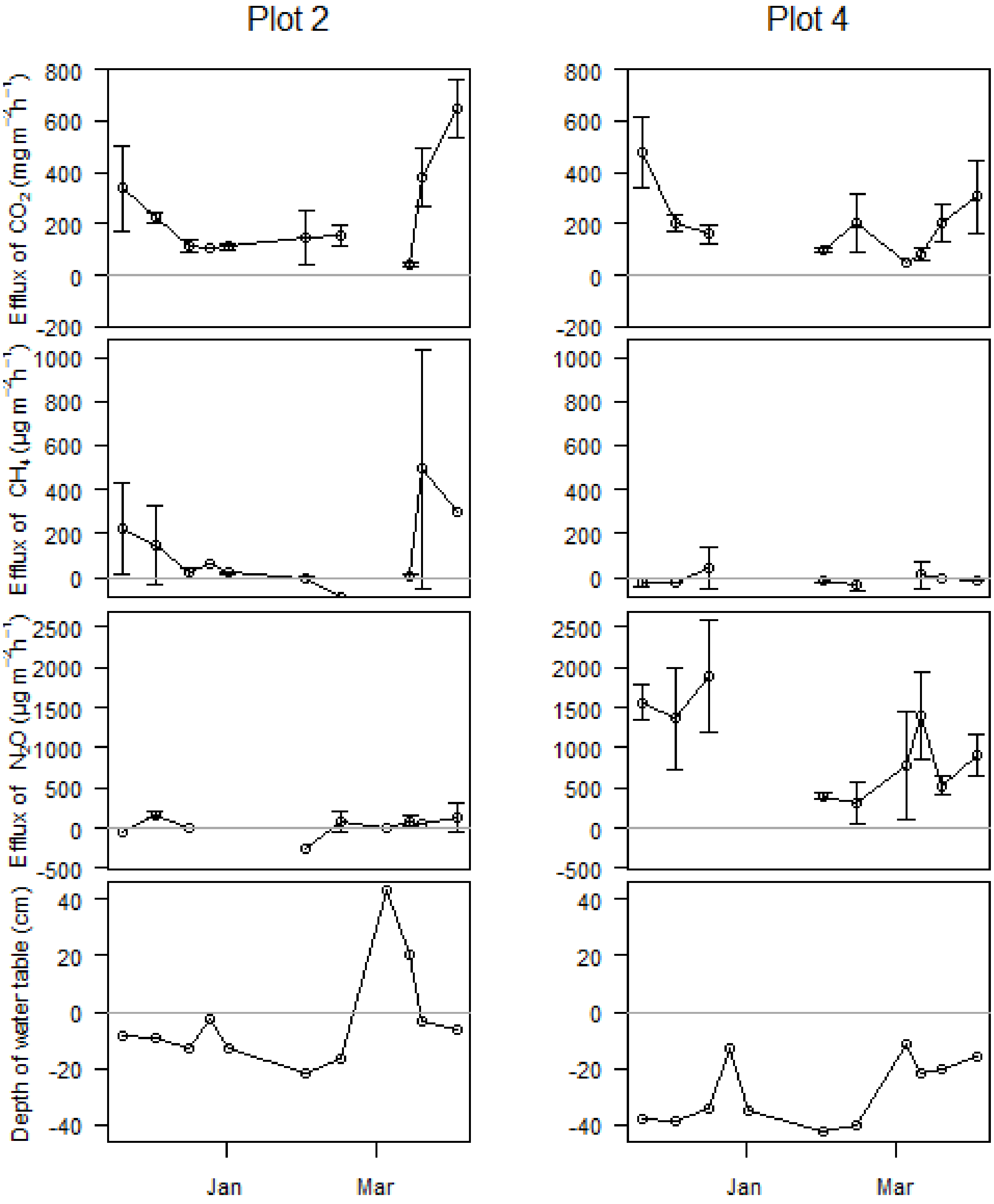

Figure 2. GHG fluxes and depth of water table (bottom row) during the measurement period of Plots 2 and 4 spanning the hydrological range of the transect (Plots 1 and 3 with intermediate water level conditions). Bars indicate the standard deviation of replicate gas flux measurements. Zero line of water table graphs marks the soil surface.

DISCUSSION

During the study period, GHG emissions from the Neuenkirchener Niederung mainly consisted of CO_2 (63 %) and N_2O (37 %).Winter CO_2 emissions from the study site were closer to winter CO_2 emissions from a boreal fen (2.5 t ha^{-1}, derived from Alm *et al.* 1999) than to winter CO_2 emissions from a maritime peat meadow (11.0 t ha^{-1}, Hendriks *et al.* 2007) indicating the impact of the extraordinary cold winter. Winter CH_4 fluxes were close to the detection limit (0.02 t ha^{-1} CO_2-eq) which is in the same order of magnitude as reported from similar fen sites in Finland (0.04 t ha^{-1} CO_2-eq, derived from Nykänen *et al.* 1995) The global warming potential (GWP) of winter N_2O emissions (2.6 t ha^{-1} CO_2-eq) was similar to the GWP of annual N_2O emissions from a drained fen in Finland (2 – 4 t ha^{-1} CO_2-eq, Nykänen *et al.* 1995) and to the GWP of winter N_2O emissions of organic grassland soils in the Netherlands (~2.8 t ha^{-1} CO_2-eq, derived from Beek *et al.* 2010). Given the cold winter and the fact of highest N_2O emissions in late autumn and early spring, we recorded a typical emission pattern from a boreal climate as described by Alm *et al.* (1999). For this reason, N_2O emissions measured in this study were possibly lower than during a climatically normal winter.

Although land use at the study site was extensified five years before the measurements were carried out and despite the cold winter, N_2O emissions of the Neuenkirchener Niederung still are as high as reported for intensively used grassland on organic soils (Velthof & Oenema 1995). Fertilization may not necessarily be needed on peatlands to produce N_2O fluxes as high as 10,000 µg ha^{-1} a^{-1} (Maljanen et al. 2009). Therefore, extensification of land use without rewetting might not lower the GHG emissions of the Neuenkirchener Niederung. According to our findings it is not a suitable measure to reduce the GWP of drained peatlands.

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