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CO_2, CH_4 AND N_2O FLUXES FROM A DRAINED BOG GRASSLAND ALONG SOIL CARBON AND MOISTURE GRADIENTS

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SUMMARY

The joint research project "Organic soils" aims at closing the data gap on the contribution of organic soils to German total GHG fluxes by monitoring emissions from eleven catchments. The former peat bog *Grosses Moor* (Gifhorn, Lower Saxony) has been altered by drainage and peat cutting. Current cultivation is grassland under extensive agricultural use. The study focused on the measurement of CO_2, CH_4 and N_2O fluxes with manual static chambers. In particular, the influence of different soil organic carbon contents (SOC) and ground water levels on greenhouse gas emissions was studied.
In 2011, CO_2 was the most important greenhouse gas. CH_4 and N_2O fluxes were on a low level as could be expected due to site conditions. Emissions were highly influenced by the groundwater table. Highest CO_2 emissions occurred at water tables 40-50 cm below ground level, temperatures above 10°C and low plant biomass values. In comparison to other factors, SOC was of minor importance.

KEY WORDS: greenhouse gases, organic soils, emission factors, peat bog, small scale gradients

INTRODUCTION

In the UN Framework Convention on Climate Change (UNFCCC) Germany committed itself to reporting greenhouse gas (GHG) emissions, including the agricultural sector. However, there is a lack of published data of GHG emissions from organic soils, which are known to be a major contributor (= key source) to German total GHG fluxes. According to the federal environmental agency (UBA) this corresponds to 5 t C ha^{-1} a^{-1} on grassland sites and 11 t C ha^{-1} a^{-1} on cropland sites (UBA 2010). Therefore, peatlands are the largest single source besides the energy sector.
The joint research project "Organic soils" and its twelve participating research institutes aim at closing the data gap by monitoring emissions from eleven catchments in Germany. Various peatlands differing in preservation and utilization are investigated in order to derive specific emission factors.
Our subproject focuses on the influence of different soil organic carbon contents (SOC) and ground water levels on the greenhouse gas emissions. Results from the first year of measurements are presented.

MATERIAL AND METHODS

The *Grosses Moor* [Great Peat Bog] (Gifhorn, Lower Saxony) is situated close to the eastern climatic boundary for bog formation and originally represented an ombrotrophic peat bog. It is located within a former moraine plain from the Saale ice age and the meltwater of the Warthe stage initiated bog formation (Overbeck 1952). During the 19th century it has been altered by peat drainage and peat cutting. Therefore, today the *Grosses Moor* is influenced by groundwater. It has a mean annual temperature of 8.5 °C and a mean annual precipitation of 663 mm (2008-2011). The mineral substrates are sandy terraces and partly Pleistocene clay layers. The formerly up to six meter deep peat layers have been altered by peat cutting, which created strong small scale heterogeneity. The original bog vegetation was nearly completely destroyed. Typical vegetation now consists of large cultivated areas, grasslands, and pine-beech-carr as well as purple moor-grass (*Molinia caerulea*), soft rush (*Juncus effusus*) and Erica heath in peat harvest areas. About 2700 hectares were transformed into restoration areas in 1984.

The study area is managed as extensive grassland with sheep grazing one to two times a year and mulching. Different organic carbon contents and moisture levels result in an inhomogeneous distribution of vegetation. Different peat cutting levels as well as differing water levels and an irregular (anthropogenic) mixing of peat layer and mineral soil result in a strong heterogeneity at a small scale. Six sites were selected and fenced for the study according to different SOC contents, water levels and the occurrence of *Sphagnum* mosses (Table 1).

Table 1. Characterization of measurement sites. Organic carbon contents, hydrological status and the occurrence of *Sphagnum* species are given.

Site	C_{org} content [%]	moisture status	*Sphagnum* species
1	25	dry	-
2	12	dry	-
3	11	moist	-
4	46	wet/seminatural	+
5	29	moist	-
6	29	wet/seminatural	+

The study focused on the measurement of CO_2, CH_4 and N_2O fluxes with manual static chambers (Drösler 2005) at the six sites. Rows of triplicate chamber frames (0.61 m², 0.4 m distance between frames) were installed on each site for gas flux measurements. Measurements were conducted at least fortnightly.

For CH_4 and N_2O flux measurements sampling was done in headspace vials and measurements were carried out with a Varian CP-3800 GC-FID/-ECD using a headspace autosampler. Diurnal cycles of CO_2 fluxes were measured with an infrared gas analyzer (LI-820, LI-COR, USA) connected to opaque (for respiration) and transparent (for net ecosystem exchange) chambers. Daily net ecosystem exchange (NEE) and ecosystem respiration (R_{eco}) were modeled according to Drösler (2005). For NEE, sites 1 to 3 and sites 4 to 6 were measured on the same day, respectively.

Soil temperatures in 0.02, 0.05, 0.01 m and ground water levels were continually logged at each site. Photosynthetic active radiation, precipitation and air temperature were continually measured at a local meteorological station. Biomass was harvested from the plots after each grazing and moist and dry weight was determined. Mineral nitrogen contents (N_{min}) were analyzed according to VDLUFA (1997).
All statistics were calculated with R (R package version 2.14.1). Package *nlme* was used for linear mixed-effects models.

RESULTS AND DISCUSSION

All research sites in the *Grosses Moor* were both source and sink of CO_2 at different times with some clear annual trends. Positive NEE values at the beginning of the year, when plants were still small, were followed by a period of negative values which coincided with vegetation growth in spring. During the summer season positive values predominated since plant and root respiration prevailed due to limited water supply (figure 1). Low water table levels during the summer season increased NEE values at highly significant levels ($p=0.0004$). SOC content had no significant influence on NEE ($p= 0.3121$).
The overall lower absolute NEE values of sites 4 to 6 in comparison to sites 1 to 3 are consistent with local site conditions. Sites 1 to 3 are rich in herbs and grasses whereas sites 4 to 6 are moss and partly *Sphagnum* dominated resulting in lower biomass productivity.
The CO_2 fluxes of the *Grosses Moor* are in the range of other studies in comparable German peatlands (e.g. Drösler 2005) as well as in peatlands of the northern latitudes (e.g. Alm et al. 1997; Bellisario et al. 1998).

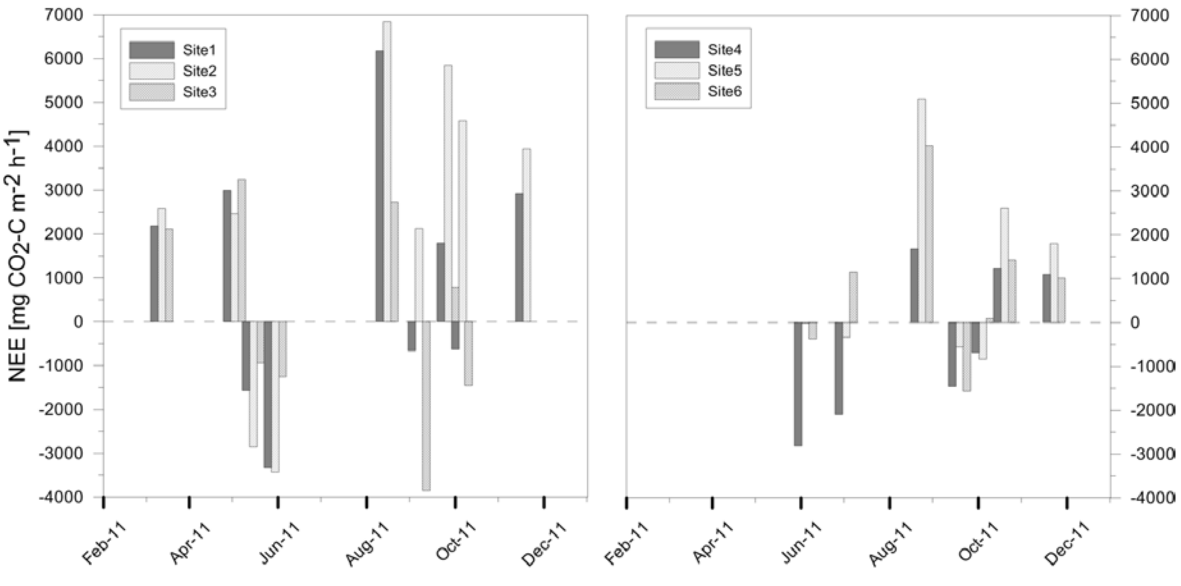

Figure 1. NEE values of distinct measurement days on sites 1 to 3 (left figure) and on sites 4 to 6 (right figure). Negative and positive values indicate net CO_2-carbon assimilation and net respiration, respectively.

CH_4 fluxes were also on a low level with mean values from 0.011 +/- 0.017 mg CH_4-C m^{-2} h^{-1} in February to 0.359 +/- 0.393 mg CH_4-C m^{-2} h^{-1} in September (figure 2). Highest CH_4 emissions were measured on site 4 whereas site 2 emitted the lowest amounts of CH_4.
Emissions were positively correlated with daily mean soil temperature in 10 cm depth ($p< 0.0001$). High groundwater tables increased this effect (interaction temperature × water table,

p=0.0005). Thus, strongest CH_4 emissions occurred during periods with high water levels and warm temperatures. Low water levels during warm periods can result in oxidation of CH_4 by Methanothrophic bacteria to CO_2 in the aerated soil zone, thereby increasing respiration. Low emission values similar to those from the dry sites (sites 1 and 2) were reported by Drösler (2005) for a dry, peat cut heath. The two sites with the highest fluxes (4 and 6) are in the lower third of average emission rates of 5-80 mg CH_4-C m^{-2} d^{-1} given by Blodau (2002).

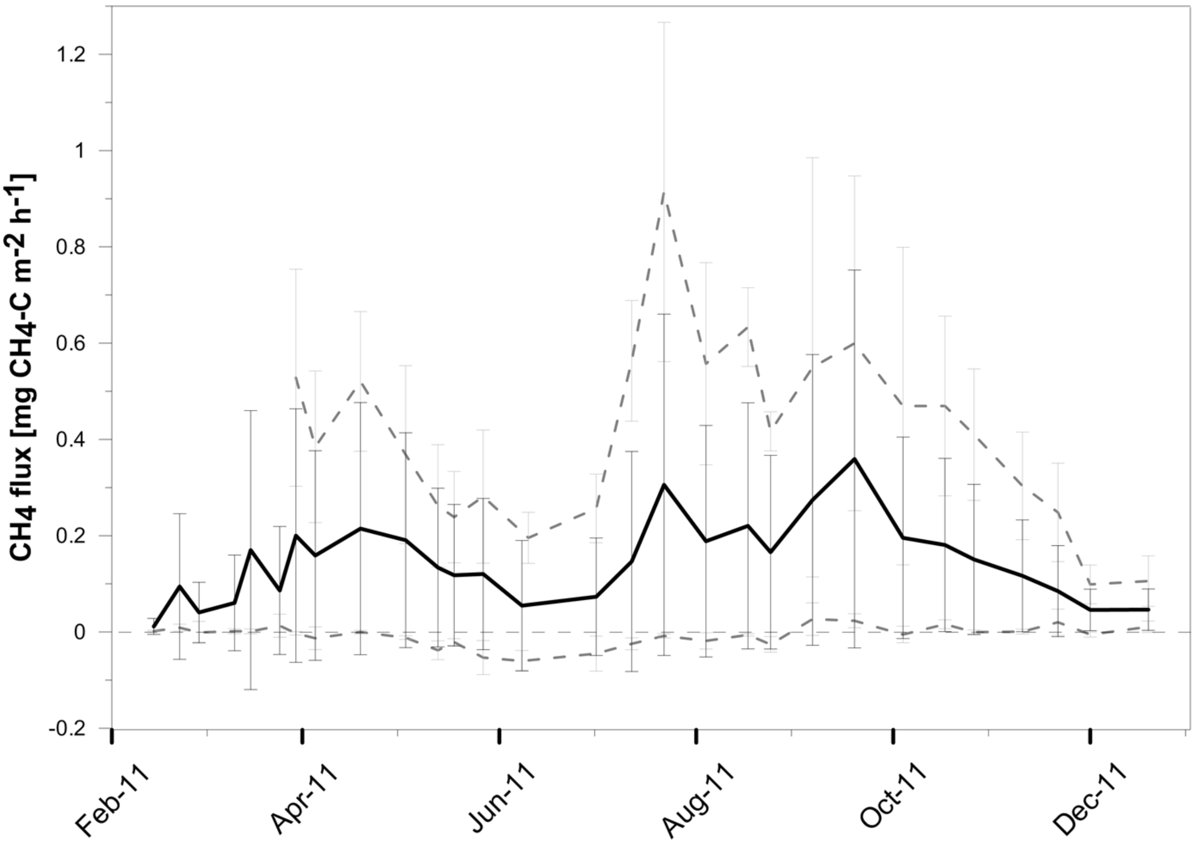

Figure 2. CH_4 fluxes during the measurement period 2011. Mean value of all 6 sites (continuous line), site 4 with the highest CH_4 fluxes (upper dashed line) and site 2 with the lowest CH_4 fluxes (lower dashed line) are depicted. Error bars of single site fluxes are standard deviation of replicate plots. Error bars of mean flux are standard deviation of site means.

N_2O fluxes were at a low level with distinct seasonal differences (figure 3). Emissions were in the range of 0.318 +/- 0.96 µg N_2O -N m^{-2} h^{-1}in February to 33.650 +/- 14.1 µg N_2O -N m^{-2} h^{-1}in May. Maximal emissions were observed at site 2 and minimal emissions at site 5. N_2O emissions were favored by low groundwater tables and high soil temperatures in 10 cm depth (interaction temperature × water table, p= 0.0011). Furthermore, N_2O-fluxes were highly correlated with CO_2 fluxes ($p<2*10^{-16}$; figure 4). Apparently, N_2O was mainly produced during the degradation of ammonia (either directly from nitrification or from denitrification coupled with nitrification) as high emissions were associated with lower ammonium concentrations (p=0.03). This was mainly observed during periods with low water levels resulting in sufficient oxygen supply and high microbial activity, which was measured as high CO_2-fluxes.

In comparison to other peat bog areas (though peat is strongly degraded at the study area) N_2O fluxes reached relatively high values, whereas values were low compared to more nutrient rich sites. Values of the same order of magnitude were reported from a dry peat cutting area by Drösler (2005).

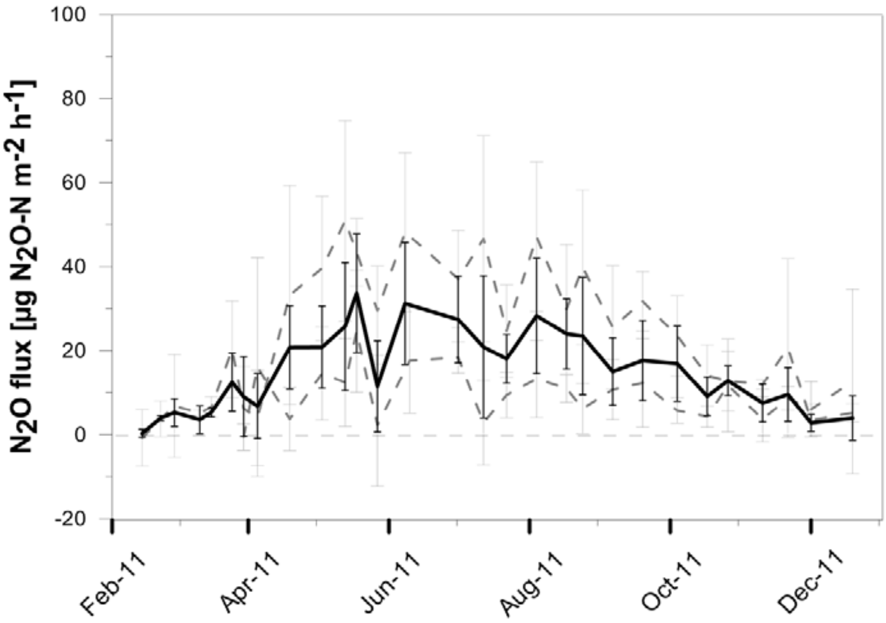

Figure 3. N_2O fluxes during the measurement period 2011. Mean value of all 6 sites (continuous line), site 2 with the highest N_2O fluxes (upper dashed line) and site 5 with the lowest N_2O fluxes (lower dashed line). Error bars of single site fluxes are standard deviation of replicate plots. Error bars of mean flux are standard deviation of site means.

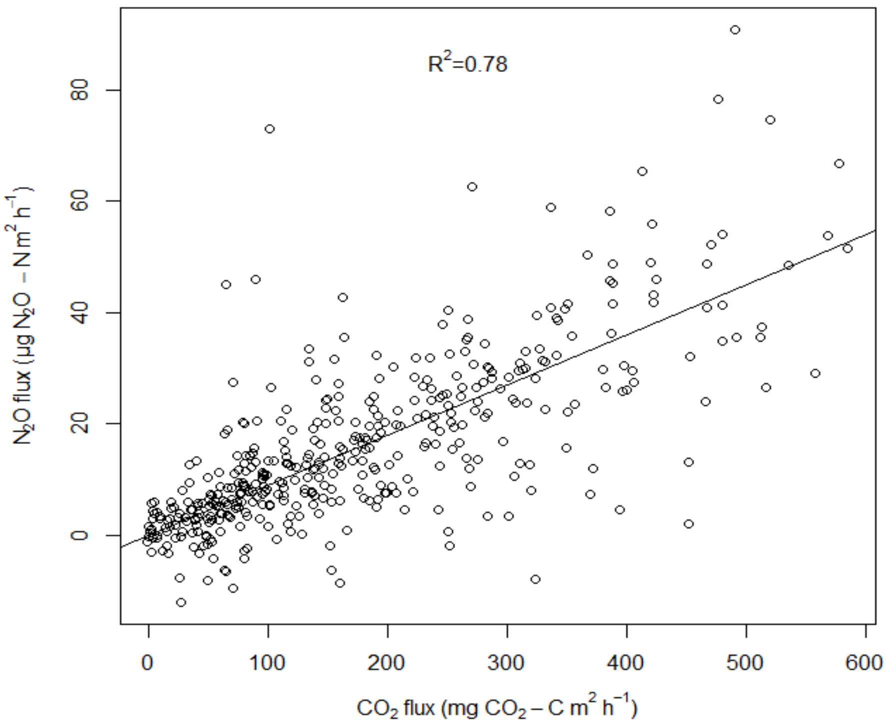

Figure 4. Correlation between CO_2 and N_2O fluxes (R^2=0.78). The regression line was forced through the origin, because the intercept of the linear regression was not significant. R² was calculated from the linear regression through the origin.

CONCLUSIONS

In 2011, CO_2 was the most important greenhouse gas. CH_4 and N_2O fluxes were on a low but according to the site conditions expected level. Emissions were significantly influenced by groundwater levels. Further influencing factors were soil temperature and vegetation composition. In comparison to other factors, SOC content was of minor importance. Therefore, organic soils with a SOC content less than 30% should also be considered in the evaluation of green house gas emissions.

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