Examensarbeten **2009:18**
Institutionen för skogens ekologi och skötsel

Importance of mire plant community composition when estimating ecosystem level methane emission

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Sammanfattning

Metan är en stark växthusgas som är viktig att ta med i beräkningarna när det gäller klimatförändringar. Feedback från myrmarker vid en ökad temperatur i samband med klimatförändringar har diskuterats, bland annat eftersom myrmarker är en källa för metan till atmosfären. Det finns många faktorer som påverkar metanemission, och en av dom är vegetation. Olika sorts vegetation tros bidra olika mycket till avgivningen av metan. Syftet med denna studie var att undersöka hur stor betydelse det har att ta med olika växtsamhällens sammansättning i beräkningarna för att uppnå korrekta uppskattningar av metanemission från myrmark på ekosystemnivå.

Mätningarna utfördes på en myr i norra Sverige under växtsäsongen 2008. Det finns permanenta ramar utplacerade på myren, och vid mättillfällena togs det luftprover från kammare som sattes ramarna. Luftproverna togs ut med en spruta och fördes sedan över till vialer som tidigare hade evakuerats. Dessa prover analyserades senare med en gaskromatograf. Det utfördes även en biomassainventering där de olika arterna torkades och vägdes.

Resultatet från studien visar att det inte finns några samband mellan biomassa och metanemission eller olika växtsamhällen och metanemission. En förklaring till det kan vara att biomassaproduktionen på den här myren inte är så stor och då bidrar inte vegtationen nämnvärt. På andra platser med högre biomassa har vegetationen förmodligen större betydelse för metanemissionen. Metanemissionen var som förväntad och överrensstämde även med resultat från andra studier.

Abstract

Methane emission is a factor to consider in climate change. Peatlands are a source of methane, and the plant community composition of the peatlands has been understood to have great importance for the methane emission to the atmosphere. The objective of this study was to investigate the importance of accounting for the plant community composition to achieve accurate ecosystem level estimates of the methane emission from a peatland.

Measurements were performed on a boreal mire in northern Sweden using a static chamber technique. A biomass inventory was also carried out. The result from the study shows no correlation between biomass and methane emission. An explanation could be that the biomass on this site is quite limited; on other sites with more biomass the vegetation probably has greater importance for the methane emission. The methane emission was as expected and corresponded with results from other studies.

Keywords: Methane, peatland, mire, biomass, plant community, boreal

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Introduction

Background

Climate change is something that is of great concern to all of us. Methane emission is a factor to consider in climate change, and the ambition for a greater understanding of methane emission from peatlands has led to more research on this topic during the last two decades.

The level of carbon dioxide in the atmosphere has increased dramatically since the preindustrial time, from 260 parts per million (ppm) in 1860 to 375 ppm in 2006 (Paul 2007). There are many possible causes for the increase, but the combustion of fossil fuels combined with the change of land use from forest to agricultural and pasture land are the two most important processes responsible. Climate change feedback from peatlands with an increase in temperature has been discussed. The plant community composition has been understood to have great influence on the release of methane from peatlands to the atmosphere. The carbon in the vegetation stored in the peatlands have once been taken up from the atmosphere, so the return of that carbon in the form of carbon dioxide would maybe not be considered as a contribution to the climate change, but the transformation of carbon dioxide to methane makes methanogens a contributor to the climate change. Methane is a very potent greenhouse gas, about 21 times more effective than carbon dioxide, but there is also an aspect of circulation time. Carbon dioxide has longer circulation time, whereas methane is very reactive with hydroxyl radicals in the atmosphere, where it forms water and carbon dioxide (Paul 2007).

Boreal peatlands cover 3% of the earth’s total land area (Matthews and Fung 1987), and are most abundant in the northern hemisphere. One third of the total soil organic carbon pool is found in peatlands (Gorham 1991). This makes them very important in the carbon balance. The long term uptake of atmospheric carbon is an important interaction with the climatic system (Paul 2007). Climate changes will probably be greatest in the northern hemisphere were most of the peatlands are located, and because of their important interactions with the climatic system it is of great importance to learn what the effect of an increase in temperature would be.

Mires and the carbon balance

Inputs of carbon to mires are through sequestration of carbon dioxide by photosynthesis, and through addition of organic via water recharge. Photosynthesis is the process where plants utilize sunlight and water to reduce atmospheric carbon into plant biomass. Losses of carbon from mires are comprised of carbon dioxide and methane, and organic carbon through runoff.

The carbon in the vegetation of the mire is stored because of the water saturation that leads to very slow decomposition of the plant material because of the lack of oxygen, and thus the production rate is greater than the decomposition rate.

Methane is produced by methanogens, a group of obligatory anoxic organisms named Archea. They are single-celled organisms that is found e.g. in the gut of humans and other animals, especially in ruminants, and in peatlands. They produce methane as a metabolic by-product. It is the last step of anaerobic decay of organic matter. They use organic carbon as electron donor and carbon dioxide as electron acceptor. The ultimate substrates are formed during fermentation, and the two most commonly used substrates for methanogenesis are hydrogen and acetate. (Paul 2007)

The methanogens produce methane in the anoxic part of the mire, and the methanotrophs consume methane in the oxic zone. The net of these two processes is the release of methane to the atmosphere. Processes that control the release of methane are reduction/oxidation and the way of transport, i.e. diffusion, ebullition, and plant mediated release.

Environmental controls of methane emission

Oxygen is the major limiting factor for methane production since the methnogens are strictly anaerobic, as mentioned earlier. When oxygen is present the methanogens are out-competed by organisms that use oxygen as electron-acceptor. Also organisms that use nitrate, sulphate or ferric iron as electron acceptor out-compete the methanogens. The availability of oxygen depends on the water table (WT). A high WT reduces the oxidized zone, thus also the oxidation of methane. Much of the methanotrophic organisms are attached to the peat particles, so their spatial distribution can not change with the WT fluctuations (Sundh et. al. 1995), as seen in figure 1. Thus, the WT influences the oxidation rate.

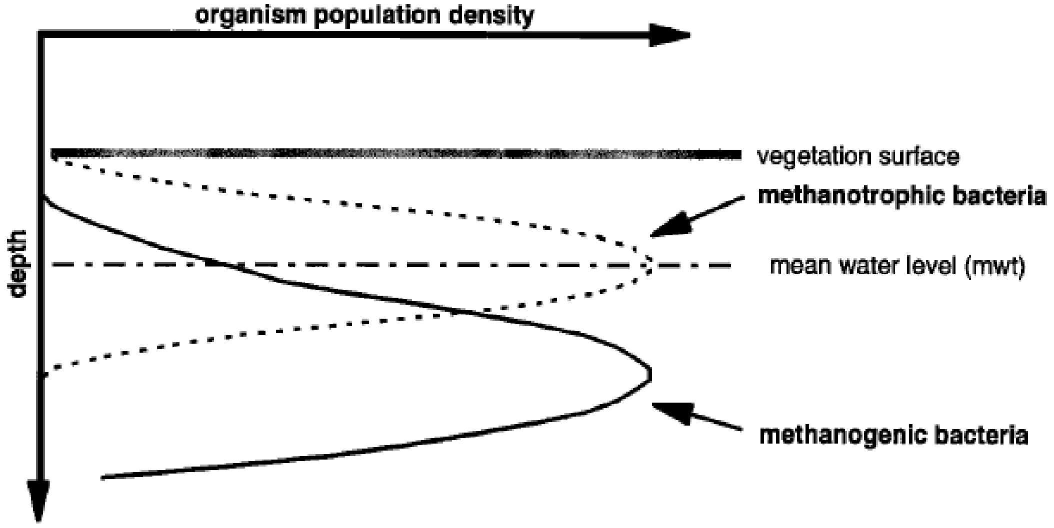

Figure 1. Generalized depth profile describing distributions of the methanogenic and methanotrophic communities in relation to the mean water table (cf. Sundh et al., 1994; Granberg et al. 1997)

Temperature is also an important factor and optimum for the methanogens is 30-40 °C. Seasonal variation in temperature correlates with the seasonal variation in methane emission. An anoxic zone close to the peat surface will respond faster to air temperature changes, while a lower anoxic zone will respond slower because of the thicker insulating peat layer on top.

Vegetation plays an important role in methane production because the carbon and energy supply to the anoxic zone is controlled both by plant root exudation and by addition of dead plant. The original composition of the plant organic matter is one of the most important factors determining the quality of the substrate for the methanogens. The other factor is the WT. The higher the WT the less decomposed the organic matter is when it reaches the zone of the methanogens and thus the quality of the substrate will be higher.

Vascular plants transport methane through aerenchyma, airy tissue that allows gas exchange between the root and the shoot. Aerenchyma is formed due to anoxic conditions in the roots. Several fresh water plants have the ability to transport gas between the rhizosphere and the atmosphere (Chanton and Whiting, 1995). This gas-mediated transport allows the methane to bypass the oxic zone of the peat where a part of it would have been oxidized. The roots also leak oxygen, and that will lead to some oxidation of methane, or at least a decrease in production because of the anoxic nature of the methanogens. (Jean le Mer 2001)

Objectives of the current study

Methane emissions often have a large spatial variation. There are several factors contributing to this, and one is the variability in vegetation. The objective of this study was to investigate the importance of accounting for the plant community composition to achieve accurate ecosystem level estimates of the emission of methane. The hypothesis is that the methane flux is higher when the proportion vascular plants are higher.

Material & Methods

Site description

Degerö Stormyr mire complex (64°11´N, 19°33´E) is located in Kulbäcksliden Experimental Forest in Västerbotten, Northern Sweden. It is situated on a highland (270 m.a.s.l.) between the rivers Umeälven and Vindelälven, approximately 70 km from the Gulf of Bothnia. The peat is mainly 3- 4 m deep, although depths of down to 8 m have been measured. The deepest peat layers correspond to an age of ~8000 years. The part of the mire complex used for the measurements presented here is a minerogenic oligotrophic mire, dominated by lawn and carpet plant communities. The climate of the site is defined as cold temperate humid.

Vegetation

The vascular plant community on this part of the mire is dominated by *Eriophorum vaginatum* L., *Trichophorum cespitosum* (L.) Hartm., *Vaccinium oxycoccos* L., *Andromeda polifolia* L. and *Rubus chamaemorus* L. with both *Carex limosa* L. and *Scheuzeria palustris* L. occurring more sparsely. The bottom layer of the carpets is dominated by *Sphagnum majus* Russ. C. Jens, and the lawns by *S. balticum* Russ. C. Jens, and *S. lindbergii* Schimp., while *S. fuscum* Schimp. Klinggr. and *S. rubellum* Wils. dominate on the more sparse hummocks.

Methane exchange measurements

For the flux measurements transparent static chambers (Plexiglas 0,48 x 0,48 x 0,3 m) were used. To reduce heating of the chamber during the measurement, a reflector (cardboard covered with aluminium foil) was attached to two of the sides and half of the top of the chamber. The reflector was directed towards the sun during measurements.

The chambers were placed on permanent stainless steel frames inserted 0,15 m into the mire surface. 32 frames were used, six frames respectively placed in four different plant communities on the mire and six frames also in the soil frost experimental area, and two in the fertilizer experimental areas. The different areas are designated; north (N), south (S), east (O), west (V), fertilizing control (G) and soil frost control (TJ). This is shown in figure 2.

Gas samples were collected with a syringe, fitted with a three-way stop valve, through a 1,5 m Teflon tubing, then transferred to evacuated glass vials, where they were allowed to equilibrate to atmospheric pressure before analysis. Gas samples were taken at the time that the chamber was installed, then every second minute up to 6 min, (i.e. four gas samples). Methane fluxes were measured approximately every second week during the snow free season. Ground water level tubes were inserted near each frame and the water level was measured at each site at the time of the methane measurements.

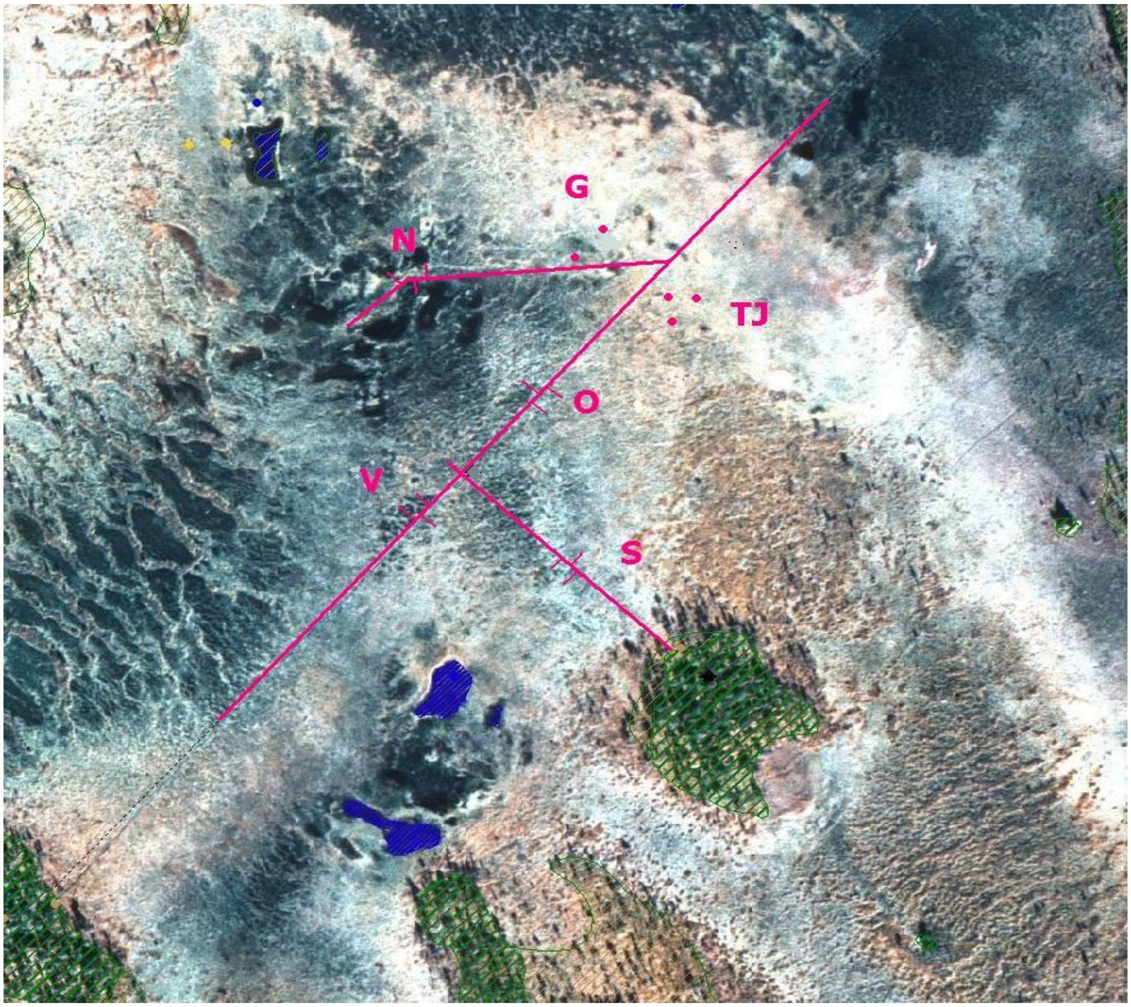

Figure 2. An image of Degerö stormyr illustrating the different sample areas. North (N), south (S), east (O), west (V), fertilizing control (G) and soil frost control (TJ).

Methane analysis

The concentration of methane in the samples was analyzed using a gas chromatograph (Auto System; Perkin Elmer, Waltham, MA, USA) equipped with a flame ionization detector (FID). The setup was as follows: stainless steel column, outer diameter 1/8", inner diameter 2,2 mm, length 2,0 m, packed with Haysep N 80/100 mesh, with nitrogen as the carrier gas supplied at 40 mL min^{-1}. The temperatures in the injector, oven and detector were 50, 35 and 100 °C, respectively.

Biomass

The biomass was collected 70 cm from each of the frames used for the methane emission measurements. A metal frame, diameter 15 cm and divided into quarters, was used as template and then a knife was used to cut the peat and vegetation in the quarter that was nearest to the board walk. The vegetation was cut 10-15 cm below the peat surface. The vegetation samples were put in plastic bags and taken in to the lab where they were placed in a freezer. The samples were removed from the freezer one day before sample treatment and analysis. First all the live vegetation, except the Sphagnum, was cut 1-2 cm below the surface of the moss. All the living part of the Sphagnum was cut, and then the capitula was separated from the rest of the moss. The woody stems of the Vaccinium and Andromeda was separated from the leaves. All the vegetation was sorted and put in aluminium container to dry in a drying oven for ~14 hours (over night). When removed from the drying oven the vessels was placed in an exicator and then weighed.

Statistics

The rate of methane emission was estimated by linear regression of the change in concentration over time. The criteria described by Granberg et al. (2001) were used to select acceptable rate estimates.

Results

Methane emissions

The methane emission from the different areas is showed in figure 3. The emissions followed the season with lower emissions in May/June and then gradually higher with a peak in July/August and then dropping again. One exception is the measurement on August 12th, where there is a drop in emission. A few days before there was a heavy rain and all the frames were flooded at the time of measurement. The highest emission of the season was from the eastern area (O) with 115 mg CH_4 m^{-2} d^{-1}.

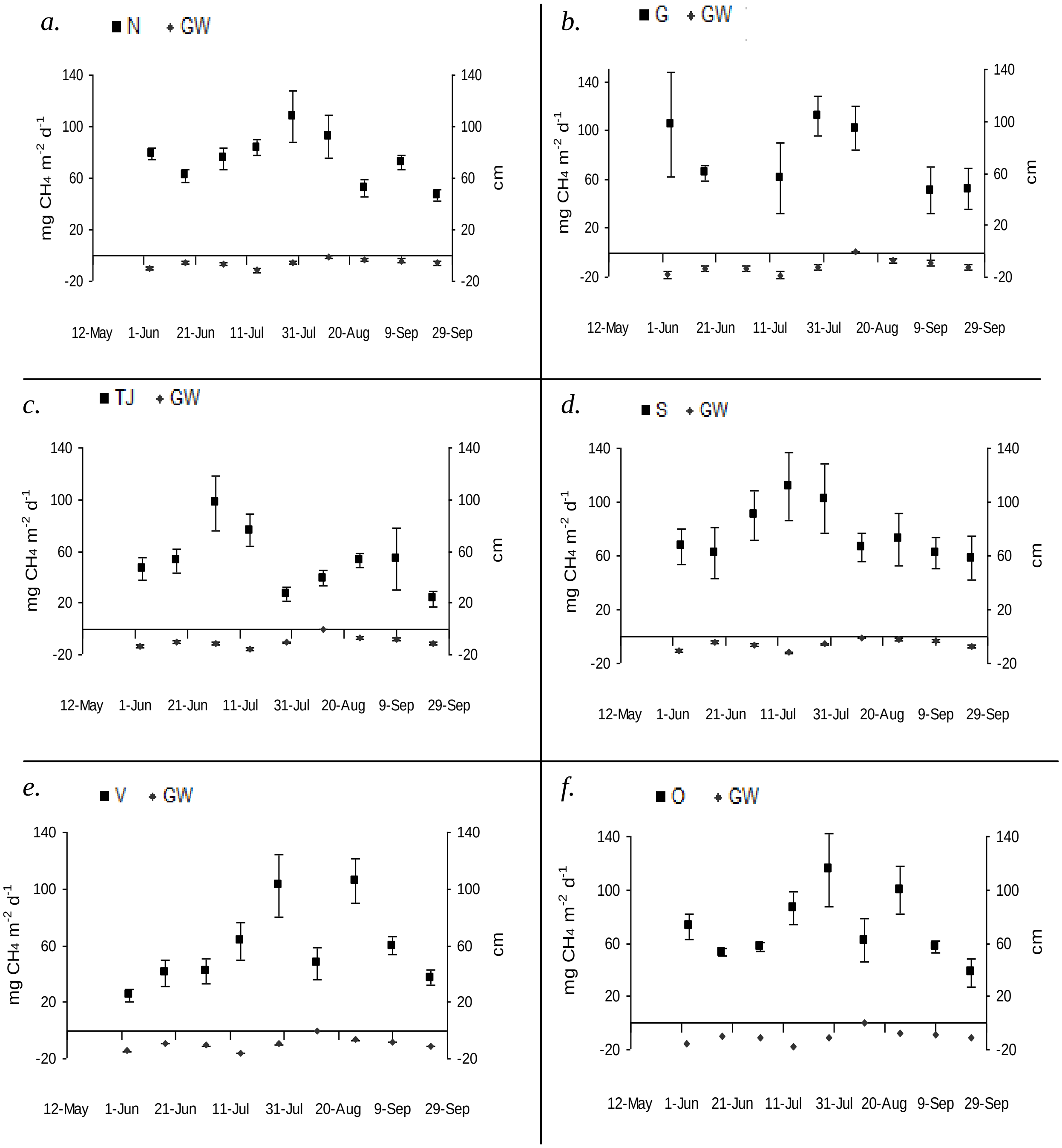

Figure 3 a-f. Mean value ±SE for methane emission (left axis) and ground water table below mire surface (right axis) in the different sample areas. The different areas are; N (north), G (fertilizing control), TJ (soil frost control), S (south), V (west), and O (east).

According to figure 4 the accumulated emission over the season was just over 10 g (G) at the most, and the lowest emission was about 7 g (N). In the same figure the mean methane emission is also shown. It follows the same pattern, but has a different scale obviously.

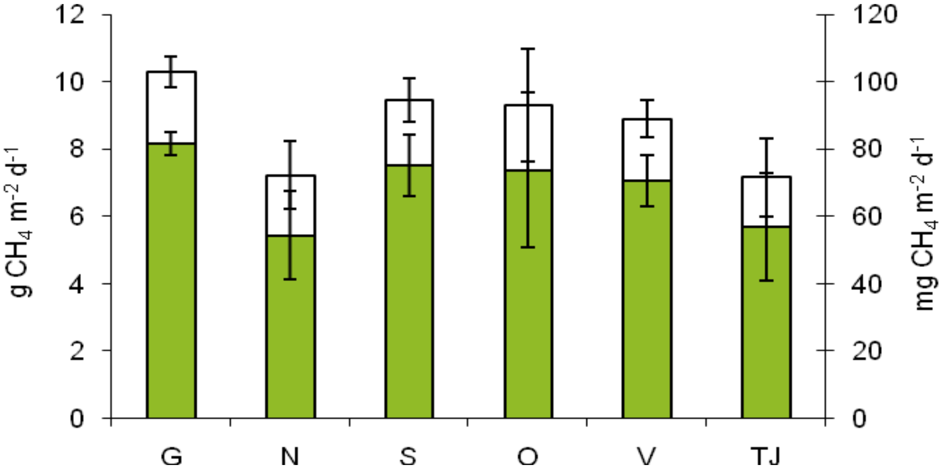

Figure 4. Accumulated season methane emission (white bars, left axis) and season mean methane emission (green bars, right axis).

Biomass

The two following figures presents the biomass of the six areas, figure 5 in percent and figure 6 shows average absolute values. The proportion Sphagnum of the total green biomass varies between 60-75% among the different areas, and the highest proportion was in the TJ area. The absolute number was also highest in the TJ area with a mean of 239 g m^{-2} for Sphagnum. The other areas were very similar in Sphagnum biomass with a range from 149 to 161 g m^{-2}. The highest proportion of the non-Sphagnum green biomass was found in the O and S areas, and the highest absolute number in the O area (90 g m^{-2}). Areas G and O had the highest proportion of non-green biomass. The areas N and V had the lowest total biomass, and TJ had the highest total biomass.

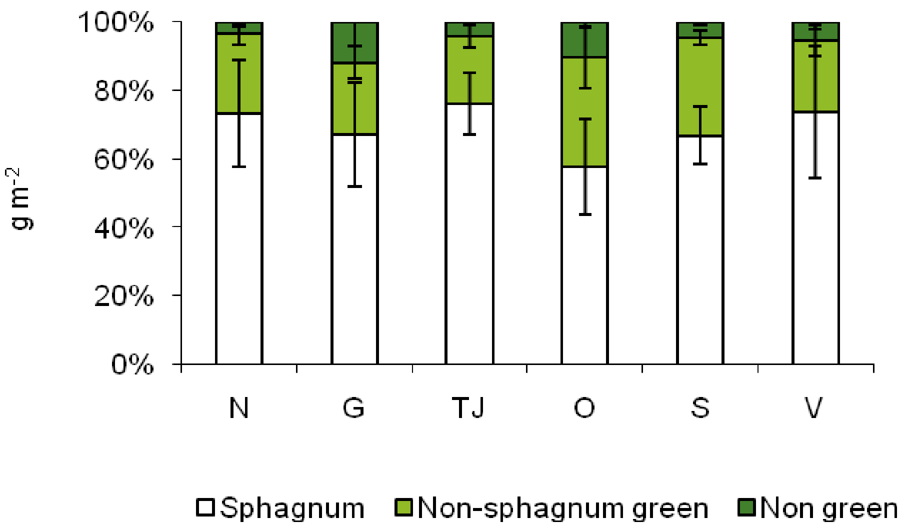

Figure 5. Biomass in percentage, divided into Sphagnum, non-Sphagnum green and non green, from the different sample areas.

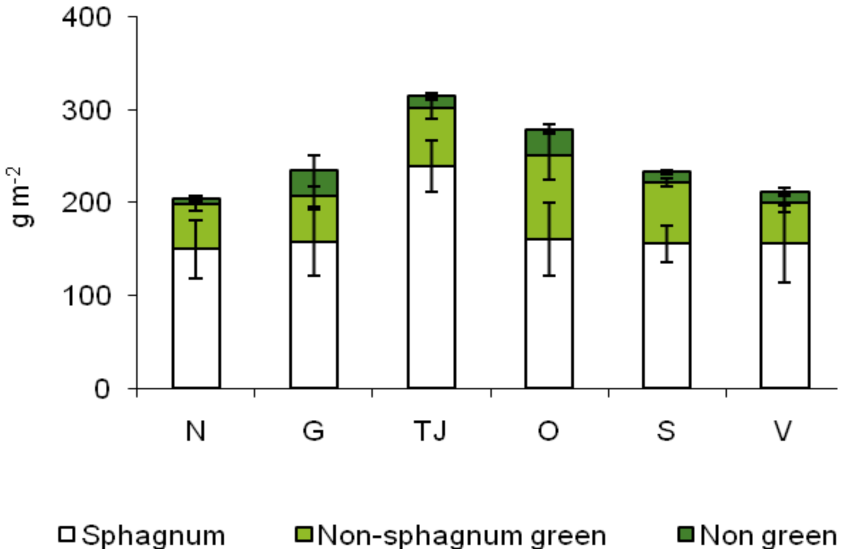

Figure 6. Biomass, divided into Sphagnum, non-Sphagnum green and non green, from the different sample areas.

Relation between plant biomass and methane emission

The relation between biomass and methane emission was tested by plotting the emission against different units of biomass. The results are presented below in figures 7 – 10, and they show no correlation between plant biomass and methane emission.

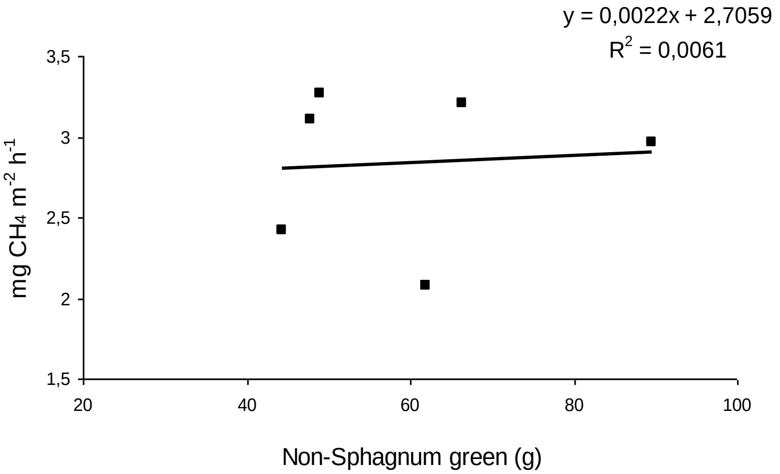

Figure 7. Correlation between methane emission and biomass (non-Shagnum green; all biomass except Sphagnum and the woody parts of the shrubs).

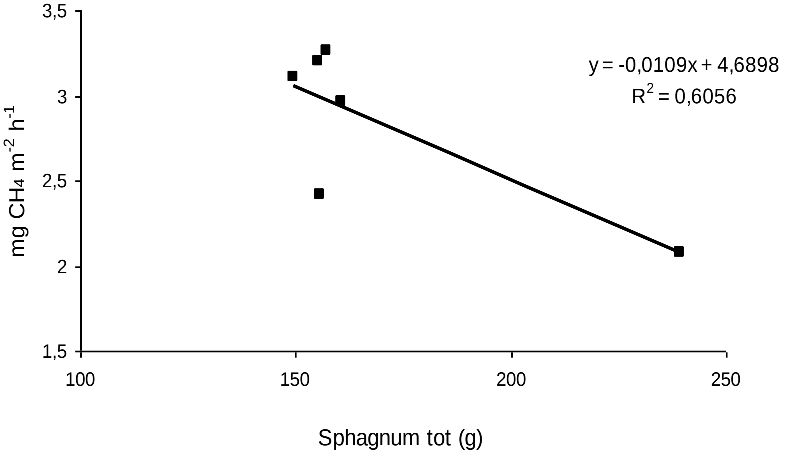

Figure 8. Correlation between methane emission and biomass (Shagnum tot; all of the Sphagnum).

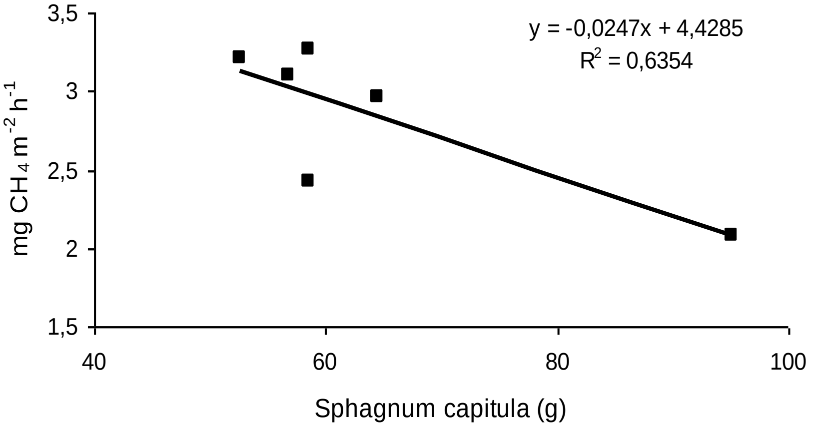

Figure 9. Correlation between methane emission and biomass (Sphagnum capitula¸ the top of the moss).

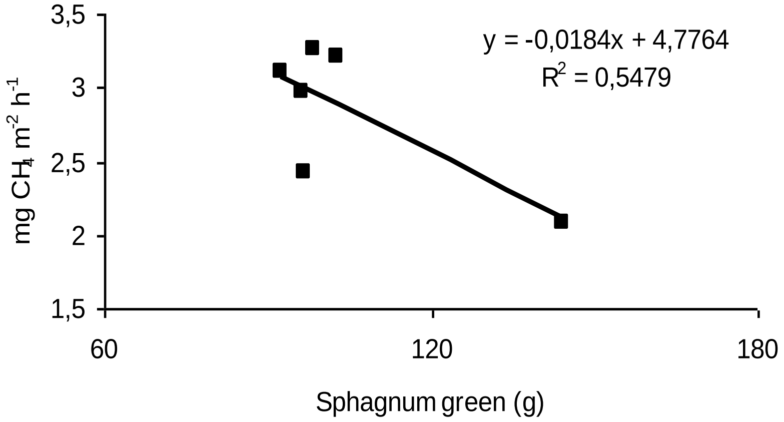

Figure 10. Correlation between methane emission and the green Sphagnum biomass (the living part of the moss except for the top).

Discussion

The accumulated methane emission over the season was between ~7 and ~10 g m^{-2}, a little lower than the annual emission data from Nykänen et al. (1998), which was between ~11 and ~14 g m^{-2}. Data from a study using the Eddy covariance technique had an average at 11.4 g m^{-2} (Rinne et al. 2007). Nykänen et al. (1998) also had seasonal averages from natural peatlands, 76.6, 79.1 and 81.5 mg m^{-2} d^{-1}, which are similar to the data from this study. The averages from this study are between 54.4 and 81.7 mg m^{-2} d^{-1}.

After the heavy rain the expected result was an increase in methane emission. In fact there was a decrease in the emission during the following measurement occasion. The reason for the decrease can be that the water from the precipitation is more oxygenated than the water standing still in the peatland, thus a decrease in methane emission due to competition between aerobic and anaerobic organisms. There is also likely a delay in emission because the methane is still produced at the same depth in the peat, but the rate of transport through diffusion through water reduced due to the increased depth of standing water above the depth of active methane production. To monitor this more measurements are needed after heavy rains.

The expected result for the relation between emission of methane and the plant biomass would be a correlation where the methane emission increases with an increase in biomass (Chanton and Whiting 1995), but the result from this study shows no correlation between the two. An explanation is that the studies showing correlation between biomass and methane emission are made in a larger scale with more biomass and a greater span in biomass. At this study area the total amount of green biomass is quite limited and also the variation in biomass between the different measurement sites is most limited. The non existing effect of variation in plant biomass on the emission of methane is most encouraging for scaling measurements of methane at the plot scale to the mire ecosystem scale. Based on this study there is no need for a detailed analysis of the relative contribution of the different plant communities to total area used for studies of the the mire – atmosphere exchange processes.

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