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Response of CH_4 emissions to moss removal and N addition in boreal peatland of northeast China

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Abstract. Boreal peatlands are an important natural source of atmospheric methane (CH_4). Recently, boreal peatlands have been experiencing increased nitrogen (N) availability and decreased moss production. However, little is known about the interactive effect of moss and N availability on CH_4 emissions in boreal peatlands. In this study, the effects of moss removal and N addition ($6\,g\,N\,m^{-2}\,yr^{-1}$) on CH_4 emissions were examined during the growing seasons of 2011, 2012 and 2013 in a boreal peatland in the Great Hinggan Mountain of northeast China. Notably, the response of CH_4 emissions to moss removal and N addition varied with experimental duration. Moss removal and N addition did not affect CH_4 emissions in 2011 and 2012, but respectively reduced CH_4 emissions by 50 % and 66 % in 2013. However, moss removal and N addition did not produce an interactive effect on CH_4 emissions. Consequently, moss removal plus N addition had no effect on CH_4 emissions in 2011 and 2012, but decreased CH_4 emissions by 68 % in 2013. These results suggest that the effects of moss removal and N enrichment on CH_4 emissions are time-dependent in boreal peatlands, and also imply that increased N availability and decreased moss growth would independently inhibit CH_4 emissions in the boreal peatlands of northeast China.

1 Introduction

Methane (CH_4), as the second most important greenhouse gas after carbon dioxide, contributes 18 % to the overall global radiative force and is predicated to play a key role in determining future climate change (IPCC, 2007). Boreal peatlands are recognized as a primary natural source of atmospheric CH_4 and contribute 1/10 of total CH_4 emissions to the atmosphere, despite covering a small area of the earth's surface (Wahlen, 1993; Moore et al., 1998; Baird et al., 2009). In boreal peatlands, CH_4 is produced by methanogens in the anaerobic layer and is then consumed by methanotrophs in the aerobic layer (Whalen, 2005). The amount of CH_4 released from peat to the atmosphere depends on the difference of CH_4-producing and CH_4-oxidizing processes in peat (Sundh et al., 1994). In boreal peatlands, CH_4 flux dynamics are influenced by soil temperature, water table position, substrate quality, microtopography and vegetation distribution (Bubier et al., 1995; Bellisario et al., 1999).

The moss layer is usually dominant in peatland ecosystems and is probably the only aerobic layer for CH_4 consumption before it enters the atmosphere (Basiliko et al., 2004). Moss provides a good thermal layer for the underlying soils and may play a role in controlling CH_4 oxidation (Basiliko et al., 2004; Turetsky, 2004). About 90 % of the CH_4 produced in peat could be consumed in the moss layer and the soil (Bubier and Moore, 1994; Whalen, 2005). It has been reported that the rate of CH_4 oxidation was $> 0.2\,\mu l\,mol\,CH_4\,g\,dry\,weight^{-1}\,h^{-1}$ by submerged brown moss (Liebner et al., 2011). However, climate change inhibits moss growth and decreases moss production in boreal peatlands (Rustad et al., 2001; Limpens et al., 2011). This could influence the CH_4 emissions from the boreal peatlands, given the important role of moss in CH_4 oxidation. Human activities have already increased nitrogen (N) input to boreal ecosystems (Vitousek et al., 1997; Kaiser, 2001) and climate warming would further stimulate the soil N mineralization rate and increase N availability in soils (Rustad et al., 2001). Previous studies regarding the effects of increased

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N availability on CH_4 emissions have yielded inconsistent results; some studies showed that increased N input increased CH_4 emissions (Saarnio et al., 2000; Granberg et al., 2001), and other studies found that N enrichment either decreased CH_4 emissions (Granberg et al., 2001) or had no effect on CH_4 production and oxidation (Saarnio and Silvola, 1999). As with climate warming, the effects of agricultural activities will expand with the increase of latitude, and the effect of high ammonium loading to boreal peatland will increase gradually, which we simulated in our study. To accurately develop the CH_4 budget in boreal peatlands, further studies are needed to examine the effect of N enrichment on CH_4 emissions.

Although previous studies have independently examined the effects of moss and N availability on CH_4 emissions (Ferenci et al., 1975; Conrad, 1999; Riutta et al., 2007; Larmola et al., 2010), there is little information about the interactive effect of moss and N addition on CH_4 emissions in boreal peatlands. Given the wide co-occurrence of declined moss growth and increased N availability in boreal peatlands, determining the effects of moss and N availability on CH_4 emissions would help to better understand CH_4 dynamics, especially in light of future climate change. In this study, a field experiment was established in a boreal peatland in the Great Hinggan Mountain in northeast China, and a 3-year (2011 to 2013) continuous observation was conducted to assess the effects of moss removal and N addition on CH_4 emissions during the growing season of a boreal peatland, to simulate the effect of environmental changes of moss degradation and N deposition on CH_4 emissions in the context of global change.

2 Materials and methods

2.1 Study site

The research was conducted in a boreal peatland ecosystem located in the north of the Great Hinggan Mountain (52°56′ N, 122°52′ E; 457 m a.s.l.) in northeast China. The study site is located in the continuous permafrost zone, and belongs to the cool continental climate (Miao et al., 2012). The mean annual precipitation (1991–2010) is ∼450 mm with 45 % falling from July to August, and the mean annual air temperature is ~ -3.9 °C with monthly mean ranging from -31.9 °C in January to 19.8 °C in July. The soil of the study site is a typical peat soil and the depth of the peat layer ranges from 40 to 100 cm, with a mean soil bulk density of $0.16\,\mathrm{g\,cm^{-3}}$, pH of 5.0, soil organic carbon of $371.68\,\mathrm{g\,kg^{-1}}$, and total N content of $17.2\,\mathrm{g\,kg^{-1}}$ at 0–20 cm depth (Sun, 2012). The amount of N deposition in the study area is approximately $0.45\,\mathrm{g\,N\,m^{-2}\,yr^{-1}}$ (Zhan et al., 2014). The dominant plant species are *Betula fruticosa*, *Ledum palustre*, *Chamaedaphne calyculata*, *Vaccinium uliginosum*, *Rhododendron parvifolium*, *Eriophorum vaginatum*, *Sphagnum moss* and *Aulacomnium androgynum*. Hummocks are covered by continuous moss with some shrubs and occupy ∼50 % of the ground surface. The height of shrubs, sedges and moss are 45–50, 30–33 and 10–12 cm, respectively. The coverage of moss is nearly 90 %, and moss biomass ranges from 190 to $400\,\mathrm{g\,m^{-2}}$.

2.1.1 Experiment design

A complete randomized block design with control (CK), moss removal (MR), N addition at $6\,\mathrm{g\,N\,m^{-2}\,yr^{-1}}$ (N) and moss removal plus N addition (MR × N) treatments was used. Each treatment was replicated three times, resulting in 12 50 cm × 50 cm plots. Plots were separated from adjacent plots by ∼1 m buffer zones, to avoid horizontal movement and lateral loss of the added N. In 2011, plots were placed on flat hummocks with a *Sphagnum* moss-dominated community. Moss was removed by cutting the green part of the moss layer (∼10 cm) in May from 2011 to 2013. The N was added as urea and applied twice a year (mid-May and mid-July). The urea was dissolved in 1 L purified water and sprayed. The control treatments were sprayed with 1 L purified water without N fertilizer.

2.2 CH_4 flux measurement

CH_4 emissions were measured by static chamber and gas chromatography at 7-day intervals between 09:00 a.m. and 11:00 a.m. during the growing periods of 2011 to 2013. The removable open-bottom chambers (stainless steel, two small fans fixed symmetrically inside, 50 cm × 50 cm × 50 cm) were put on the base flumes (stainless steel, 50 cm × 50 cm × 30 cm) during sample collecting, and immediately removed after collection. The grooves (2 cm wide) of the base collar were filled with water to ensure gas tightness. Gas samples were taken at 0, 10, 20 and 30 min from the chamber headspace following closure by 60 mL plastic syringes attached to three-way stopcocks. Immediately, the samples were stored in 100ml vacuum Tedlar® air sample bags, and analyzed within a week in the laboratory by modified gas chromatography (Agilent HP-7820A, USA), which was modified by adding an independent sample injector by the Institute of Atmospheric Physics, Chinese Academy of Sciences, and equipped with a flame ionization detector. Details and configurations of the measuring system for analyzing concentrations of CH_4 and the associated method for calculating the flux have been described by Wang and Wang (2003) and Song et al. (2009). Where the linear regression with coefficients of determination (R^2) were < 0.8, the samples were rejected for CH_4.

2.2.1 Precipitation, soil moisture and soil temperature

Precipitation was measured by a rain gauge located near the experimental area. Soil moisture at 5 and 10 cm depth were recorded using a portable time-domain reflectometry

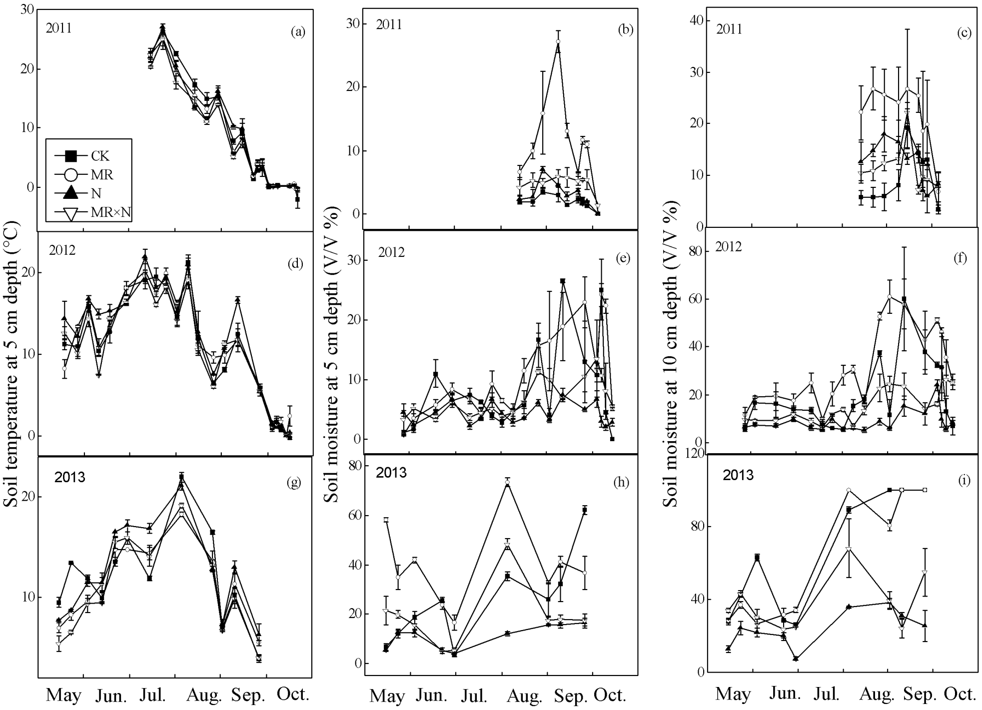

Figure 1. Temporal dynamics of soil temperature at 5 cm depth **(a, d, g)**, soil moisture at 5 cm depth **(b, e, h)** and soil moisture at 10 cm depth **(c, f, i)** during the growing seasons in 2011, 2012 and 2013. Data are daily averages for each treatment (± SE, $n = 3$). CK, control; MR, moss removal; N, N addition; MR × N, moss removal plus N addition

instrument (Field Scout TDR-100, Spectrum Technologies Inc., Plainfield, IL, USA) in each plot. Soil moisture data recorded as the percentage of volumetric moisture content was measured during gas sampling from 7 July to 17 October in 2011, from 17 May to 12 October in 2012 and from 14 May to 22 September in 2013. Soil temperatures at 5 cm below the peat surface were collected in the center of each plot using the portable digital thermometer (JM 624, Jinming Instrument CO., Ltd, Tianjin, China).

2.2.2 Statistical analysis

The seasonal mean values were calculated by averaging the monthly mean values from May to October, and then it was multiplied by the number of experimental days and the CH_4-C transformed was the seasonal carbon (C) budget. A p value of < 0.05 was considered significant unless otherwise stated. Dependent variables were tested for normality by the Kolmogorov–Smirnov test, and were log-transformed when data were not following the normal distribution. One-way ANOVA was used to examine the differences in seasonal C budget among treatments, followed by Tukey's or Tamhane's multiple comparison test. Repeated measures of ANOVAs were used to examine the effects of sampling dates, moss removal and N addition on CH_4 flux and soil moisture. In each year, two-way ANOVAs were used to assess the effects of moss removal, N addition and their interactions on CH_4 budgets. Linear regression analysis was conducted to examine the relationship between CH_4 flux and soil moisture or soil temperatures. All the statistical analyses were tested using SPSS package 16.0 (SPSS Inc., Chicago, IL, USA), and figures were conducted by Origin 8.0 (Origin Lab Corporation, USA) and SigmaPlot 12.0 (Systat Software, Inc. USA) for Windows.

3 Results

3.1 Precipitation, soil moisture, soil temperature and biomass

Precipitation showed great annual variations during the sampling periods. The precipitation during the growing seasons of 2011 (496.2 mm) and 2012 (347.1 mm) was 28.8 % higher and 9.9 % lower than the 20-year (1991–2010) mean annual value (385.4 mm), respectively, whereas total precipitation during the growing season in 2013 (621.4 mm) was much higher than the 20-year mean annual value. Annual fluctuations in precipitation resulted in the highest soil moisture in 2013 ($p < 0.001$). Moss removal significantly increased soil moisture at 5 cm ($p < 0.001$) in all years, whereas N addition significantly decreased soil moisture ($p < 0.001$) in 2012 and 2013. Both moss removal and N addition significantly increased soil moisture ($p < 0.01$) in

Table 1. Results (F values) of repeated measures ANOVAs on the effects of N addition (N), moss removal (MR), sample times and their interactions on CH_4 flux ($g\,CH_4\,m^{-2}\,h^{-1}$), soil temperature (°C) at 5 cm depth, soil moisture (%) at 5 cm depth and soil moisture (%) at 10 cm depth.

	CH_4 fluxes			Soil temperature at 5 cm depth			Soil moisture at 5 cm depth			Soil moisture at 10 cm depth		
	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
N	2.62	1.54	7.59^{*}	1.69	0.34	4.39	4.89	93.98^{***}	250.60^{***}	0.39	52.66^{***}	306.82^{***}
MR	3.24	1.94	5.42^{*}	5.91^{*}	1.20	4.05	89.02^{***}	70.13^{***}	120.58^{***}	4.58	37.91^{***}	27.82^{**}
MR × N	0.03	0.001	2.57	0.35	18.00^{**}	1.07	17.94^{**}	0.16	10.23^{*}	5.39^{*}	1.39	54.69^{***}
Time	6.13^{***}	5.88^{***}	36.62^{***}	608.31^{***}	393.16^{***}	21.65^{**}	3.73^{*}	18.80^{***}	52.31^{***}	5.40^{**}	16.95^{***}	59.72^{***}
Time, × N	1.61	0.53	7.46^{*}	2.28	1.10	9.19^{*}	0.81	7.31^{***}	6.68^{***}	2.47	4.96^{**}	10.48^{***}
Time, × MR	1.47	0.81	3.61	2.87^{*}	4.83^{**}	0.51	2.29	4.74^{**}	24.61^{***}	0.74	4.67^{**}	8.02^{**}
Time, × N, × MR	0.54	0.20	5.01^{*}	1.35	4.42^{**}	0.59	1.34	2.00	6.62^{***}	3.16	1.42	4.27^{*}

*, **, and *** represent significant at $p < 0.05$, 0.01, and 0.001, respectively.

Table 2. Results (F Values) of two-way ANOVAs on the effects of N addition (N), moss removal (MR) and their interactions on CH_4 flux ($g\,CH_4\,m^{-2}\,h^{-1}$).

	2011	2012	2013	Average
N	2.16	1.22	18.34^{**}	11.78^{**}
MR	3.87	1.65	5.64^{*}	5.56^{*}
MR × N	0.01	0.001	4.02	2.10

* and ** represent significant at $p < 0.05$ and 0.01, respectively.

2011, but significantly decreased ($p < 0.05$) it in 2013 (Table 1, Fig. 1b, e, h). Moss removal significantly increased soil moisture at 10 cm ($p < 0.001$) in 2012, but significantly decreased ($p < 0.01$) it in 2013, whereas N addition significantly decreased ($p < 0.001$) it in both 2012 and 2013. The addition of N interacted with moss removal significantly and increased ($p < 0.05$) soil moisture in 2011, but significantly decreased ($p < 0.001$) it in 2013 (Table 1, Fig. 1c, f, i). Soil temperature at 5 cm significantly increased under moss removal in 2011 ($p < 0.05$), whereas N addition showed no effect ($p > 0.05$) in all years. Moss removal and N addition produced a significant interaction on soil temperatures ($p < 0.01$) in 2012 (Table 1, Fig. 1a, d, g).

The aboveground biomass of the re-growth of moss was $1.48\,g\,m^{-2}\,yr^{-1}$ without N addition, and $0.69\,g\,m^{-2}\,yr^{-1}$ with N addition. The total biomass of sedges decreased 11.8 and 16.3 % by moss removal and N addition, respectively. The total biomass of shrubs increased 18.6 % by moss removal, and 94.4 % by N addition. Moss removal decreased the total biomass of moss by 33.5 %, and N addition decreased 13.9 % (Table 3). However, moss removal and N addition did not produce significant effects on total biomass of sedges, shrubs and moss, ($p > 0.05$).

3.2 Effects of moss removal and N addition on CH_4 flux

Moss removal significantly reduced CH_4 emissions by 50.4 % in 2013 ($p < 0.05$; Table 1, Fig. 2c), but had no significant effects in 2011 and 2012 ($p > 0.05$; Table 1, Fig. 2a, b). The N addition showed a significant negative effect on CH_4 emissions in 2013 (65.8 %, $p < 0.05$), but did not significantly affect it in 2011 and 2012 ($p > 0.05$). However, moss removal and N addition did not produce an interactive effect on CH_4 emissions during the whole sampling period (Table 2). Moss removal and N addition decreased CH_4 emissions by 68.5 % in 2013, but had no effect in 2011 and 2012.

There were substantial annual variations in CH_4 emissions ($p < 0.001$). In the control plots, the average CH_4 emission rate during the growing season was $1.89\,mg\,CH_4\,m^{-2}\,h^{-1}$

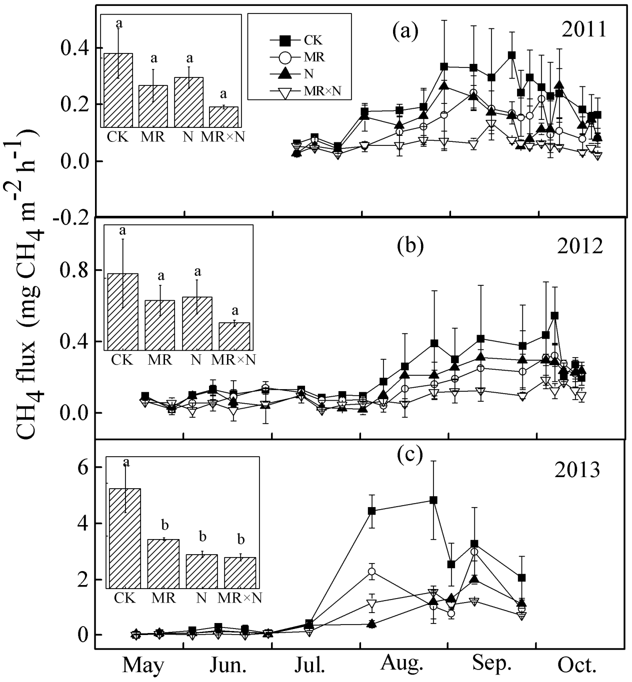

Figure 2. Temporal dynamics of CH_4 flux during the growing seasons in 2011, 2012 and 2013. Data are daily means (±SE, $n = 3$). Insets represent the seasonal means. CK, control; MR, moss removal; N, N addition; MR × N, moss removal plus N addition. Different lowercase letters indicate significant differences among treatments ($p < 0.05$).

Table 3. Effects of N addition and moss removal on aboveground, belowground biomass and total biomass.

	Aboveground biomass ($g\,m^{-2}$)			Belowground biomass ($g\,m^{-2}$)			Total biomass ($g\,m^{-2}$)		
	Shrubs	Sedges	Moss	Shrubs	Sedges	Moss	Shrubs	Sedges	Moss
CK	212 ± 0.67	85.25 ± 9.32	18.72 ± 0.95	33.47 ± 1.69	16.53 ± 0.65	57.51 ± 2.74	61.37 ± 1.79	25.44 ± 9.91	19.06 ± 1.79
MR	254.31 ± 15.99	86.68 ± 6.46	1.48 ± 0.42	36.82 ± 2.81	3.04 ± 0.07	50.17 ± 5.50	72.78 ± 5.39	22.43 ± 6.40	12.67 ± 5.39
N	427.89 ± 22.64	84.92 ± 8.67	9.40 ± 1.02	49.33 ± 5.72	0.22 ± 0.01	56.23 ± 0.54	119.31 ± 1.33	21.29 ± 8.66	16.40 ± 1.33
MR × N	312.3467 ± 23.48	102.87 ± 6.30	0.69 ± 0.03	48.98 ± 3.05	5.21 ± 0.47	55.41 ± 3.74	90.33 ± 3.69	27.02 ± 5.83	13.91 ± 3.69

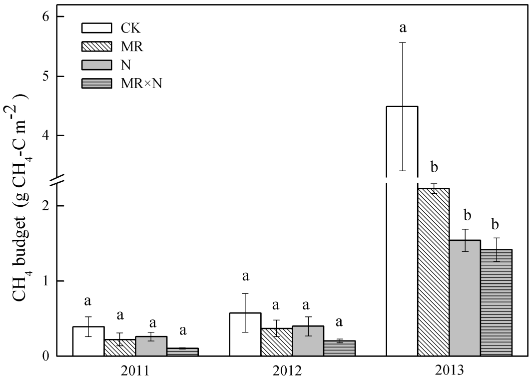

Figure 3. Annual CH_4 budget in 2011, 2012 and 2013. Error bars represent standard errors ($n = 3$). CK, control; MR, moss removal; N, N addition; MR × N, moss removal plus N addition. Different lowercase letters indicate significant differences among treatments ($p < 0.05$).

in 2013, which was 800 % higher than those in 2011 ($0.21\,mg\,CH_4\,m^{-2}\,h^{-1}$) and 2012 ($0.21\,mg\,CH_4\,m^{-2}\,h^{-1}$) (Fig. 2). The CH_4 flux significantly varied with sampling dates during the three growing seasons ($p < 0.001$, Table1). The N addition interacted with the sampling dates to significantly affect CH_4 flux in 2013 ($p < 0.05$). Similarly, N addition significantly interacted with moss removal or sampling dates to affect CH_4 flux ($p < 0.05$). However, moss removal and sampling dates did not produce an interaction on CH_4 flux ($p > 0.05$, Table 1).

Across the three growing seasons, CH_4 flux exhibited a weak negative relationship with increased soil temperatures ($R^2 = 0.02$, $p < 0.05$, Fig. 4a), and showed a positive linear dependence on soil moisture at 5 and 10 cm ($R^2 = 0.22$, $p < 0.01$, Fig. 4b; $R^2 = 0.39$, $p < 0.01$, Fig. 4c). In all 12 treatments, CH_4 flux was positively and linearly correlated with soil moisture at 5 cm in both 2012 ($R^2 = 0.32$, $p < 0.01$, Fig. 5e) and 2013 ($R^2 = 0.20$, $p < 0.05$, Fig. 5h), and soil moisture at 10 cm in both 2012 ($R^2 = 0.30$, $p < 0.01$, Fig. 5f) and 2013 ($R^2 = 0.54$, $p < 0.01$, Fig. 5i), but negatively and linearly with soil temperatures at 5 cm in 2012 ($R^2 = 0.33$, $p < 0.01$, Fig. 5d).

4 Discussion

Moss removal and N addition were found to have no effects on CH_4 emissions in 2011 and 2012, but to significantly decrease CH_4 emissions in 2013. These results imply that the effects of moss removal and N addition on CH_4 emissions vary with experiment duration and suggest that long-term studies are needed to accurately develop the CH_4 budget in boreal peatlands.

In this study, moss removal had no effect on CH_4 emissions in 2011 and 2012, and produced a negative effect in 2013. Methanogens produced CH_4 in strictly anaerobic conditions and were limited by substrate availability (Yavitt et al., 2012). Moss removal decreased belowground biomass (Table 3) that in turn may reduce C substrates for methanogens. Moss would absorb rainfall, saturating the moss layer and forming anaerobic conditions. Therefore, moss removal would decrease substrate for methanogens in soil and moss mats (Riutta et al., 2007) and decrease CH_4 production. Meanwhile, moss removal would decrease soil moisture through evaporation and form aerobic conditions (Amaral and Knowels, 1995). Larmola et al. (2010) observed that methanotrophy was less frequent on high hummocks, and the oxidation rates were not detectable. It could have already been oxidized belowground near the water table. Therefore, moss removal may lead to more aerobic conditions for methanotrophy and stimulate CH_4 oxidation in soil. Therefore, moss removal would decrease CH_4 emissions in boreal peatlands. The results from this study showed that the effect of moss removal on CH_4 emissions were time-lagged in boreal peatlands.

Similar to moss removal, N addition had no effect on CH_4 emissions in 2011 and 2012, but inhibited CH_4 emissions in 2013 in the boreal peatland in this study. Previous studies also found that N addition effects on CH_4 emissions were inconsistent. Saarnio et al. (2000) and Granberg et al. (2001) reported that N input increased CH_4 emissions in the peatland. In contrast, Granberg et al. (2001) showed that N enrichment decreased CH_4 emissions in a fen. In addition, Saarnio and Silvola (1999) found no response of CH_4 production and oxidation to N addition. The major environmental factors that affect CH_4 emissions in peatland include temperature, water table and substrate properties, for instance, mineral nitrogen content (Melling et al., 2006). Climate warming is predicted to increase microbial activity, and

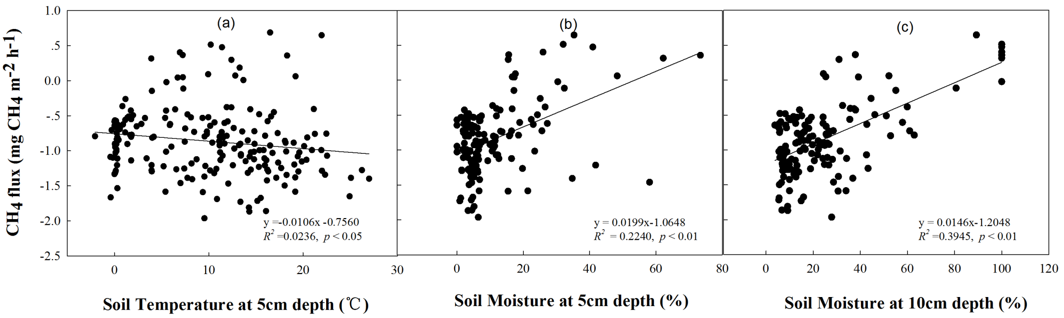

Figure 4. Temporal dependence of CH_4 flux on soil temperature **(a)** and soil moisture **(b, c)** across the three growing seasons.

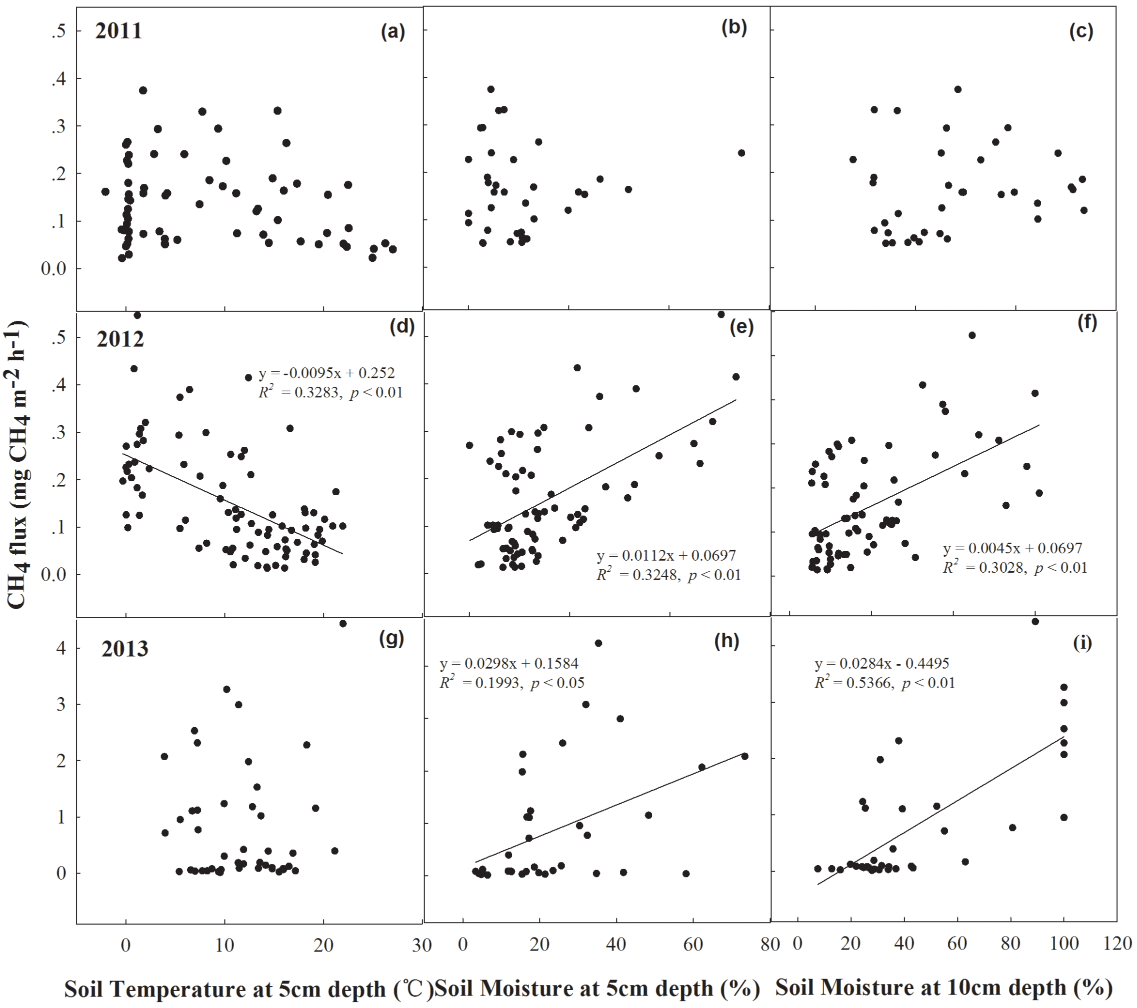

Figure 5. The relationships between mean CH_4 flux and soil temperature at 5 cm depth **(a, d, g)**, soil moisture at 5 cm depth **(b, e, h)** and soil moisture at 10 cm depth **(c, f, i)**, respectively.

further urge urea to be mineralized to ammonium in soils. Meanwhile, the change of water environment in soil may also affect the dissolving process of urea and microbial activity. These would lead to high ammonium loading in boreal peatlands in northeast China. Moss and vascular plants intercepted the added N in the initial 2 years, which made N unavailable to soil microbes (Nordin et al., 1998; Saarnio and Silvola, 1999; Bobbink et al., 2010). Growth reduction would occur as moss saturated with N (Baxter et al., 1992; Gunnarsson and Rydin, 2000; Limpens et al., 2011) and the loss of biomass production would be further stimulated (Lamers et al., 2000; Limpens et al., 2011). However, N deposition would stimulate the growth of vascular plants (Tomassen et al. 2004). Therefore, substrate for microbes may be balanceable in the moss-dominated ecosystem. Hence, N addition did not affect CH_4 emissions in 2011 and 2012 in the boreal peatland. The subsequent negative effect of N addition on CH_4 emissions in 2013 was explained by the following mechanisms. Firstly, N addition inhibited methanogenesis, due to competition for hydrogen with some microbes and toxicity of denitrification products to the methanogens, including nitrite, NO and/or N_2O (Conrad, 1999). Secondly, N addition promoted CH_4 oxidation by methanotrophs (Bodelier et al., 2000; Bodelier and Laanbroek, 2004). Previous studies found that ammonium enhanced the development and activity of microorganisms, especially methanotrophs (Bodelier and Laanbroek, 2004) and hence stimulated CH_4 oxidation in the rhizosphere of the plant (Bodelier et al., 2000).

Notably, moss removal and N additions did not produce an interactive effect on CH_4 emissions in the boreal peatland of this study. CH_4 emissions depended on the balance among methanogenesis, CH_4 oxidation and CH_4 transport. In peatlands, methanogenesis and CH_4 oxidation were controlled mainly by soil temperature, soil moisture (or water table below the surface) and substrates (Yavitt et al., 2012). In this study, the mechanisms that controlled the combined effects of moss removal and increased N input on CH_4 emissions in a boreal peatland ecosystem have not been fully elucidated. Nevertheless, the results suggest that moss removal and N addition independently affect CH_4 emissions in boreal peatlands.

The mean CH_4 budget in the control plots ranged from $0.39\,\mathrm{g\,C\,m^{-2}}$ in 2011 to $4.49\,\mathrm{g\,C\,m^{-2}}$ in 2013 (Fig. 3), and varied substantially with annual precipitation over the study period in boreal peatland. These results imply that altered precipitation regimes and increased extreme weather would exert profound influences on CH_4 emissions in boreal peatland in the context of global climate change.

5 Conclusions

In this study, we simultaneously assessed the impact of moss removal and N enrichment on CH_4 emissions during the growing seasons of 2011, 2012 and 2013 in a boreal peatland of northeast China. Neither moss removal nor N addition affected CH_4 emissions in 2011 and 2012, but suppressed them in 2013. Moreover, moss removal and N addition did not produce an interactive effect on CH_4 emissions. These results suggest that the effects of moss removal and N addition on CH_4 emissions are time-dependent, and long-term studies are needed to accurately develop knowledge of CH_4 emissions in boreal peatlands in the context of global climate change. Meanwhile, these results also imply that moss removal and N addition independently suppressed CH_4 emissions in boreal peatlands in northeast China.

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