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Effects of environmental factors on N_2O emission from and CH_4 uptake by the typical grasslands in the Inner Mongolia

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Abstract

The fluxes of N_2O emission from and CH_4 uptake by the typical semi-arid grasslands in the Inner Mongolia, China were measured in 1998–1999. Three steppes, i.e. the ungrazed *Leymus chinensis* (*LC*), the moderately grazed *Leymus chinensis* (*LC*) and the ungrazed *Stipa grandis* (*SG*), were investigated, at a measurement frequency of once per week in the growing seasons and once per month in the non-growing seasons of the *LC* steppes. In addition, four diurnal-cycles of the growing seasons of the *LC* steppes, each in an individual stage of grass growth, were measured. The investigated steppes play a role of source for the atmospheric N_2O and sink for the atmospheric CH_4, with a N_2O emission flux of 0.06–0.21 $\mathrm{kg\,N\,ha^{-1}\,yr^{-1}}$ and a CH_4 uptake flux of 1.8–2.3 $\mathrm{kg\,C\,ha^{-1}\,yr^{-1}}$. Soil moisture primarily and positively regulates the spatial and seasonal variability of N_2O emission. The usual difference in soil moisture among various semi-arid steppes does not lead to significantly different CH_4 uptake intensities. Soil moisture, however, negatively regulates the seasonal variability in CH_4 uptake. Soil temperature of the most top layer might be the primary driving factor for CH_4 uptake when soil moisture is relatively low. The annual net emission of N_2O and CH_4 from the ungrazed *LC* steppe, the moderately grazed *LC* steppe and the ungrazed *SG* steppe is at a CO_2 equivalent rate of 7.7, 0.8 and −7.5 $\mathrm{kg\,CO_2\text{-}C\,ha^{-1}\,yr^{-1}}$, respectively, which is at an ignorable level. This implies that the role of the semi-arid grasslands in the atmospheric greenhouse effect in terms of net emission of greenhouse gases (CO_2, CH_4 and N_2O) may exclusively depend upon the net exchange of net ecosystem CO_2 exchange.

Keywords: Nitrous oxide; Methane; Semi-arid grassland; Soil moisture

1. Introduction

Nitrous oxide and methane are the most important greenhouse gases in the atmosphere. In recent decades, their concentrations in the atmosphere have been rising very rapidly. At present, the increase rate of CH_4 and N_2O is 1.1% and 0.25%, respectively (IPCC, 2001). The rising concentrations of atmospheric CH_4 and N_2O are considered as a contributor for global warming. It is regarded that increased biospheric production and decreases in global sinks are the substantial reasons for the rapid enhancement of these greenhouse gases (e.g. Houghton, 1994).

Grassland is one of the most important global terrestrial ecosystems, covering about 25% of the global terrestrial area (Tieszen and Detling, 1983). Changes in the exchange of greenhouse gases between grassland ecosystems and the atmosphere, therefore, may significantly impact on the global climate change. Mosier et al.

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(1991, 1993, 1996, 1997) have carried out a multi-year research in the Colorado short-bunchgrass steppes of America and have indicated that temperate grasslands, which currently account for ~8% of the Earth's surface, may be very important to balance the budget of atmospheric N_2O. Velthof and Oenema (1995, 1997) have concluded that grazing has increased N_2O emission from fertilized grasslands in the Netherlands. Dobbie and Smith (2003) have consolidated the idea that rainfall is the main driving factor for N_2O emission during the growing season of grasslands. The natural grasslands of China cover an area of 3.9×10^8 ha, accounting for about 41% of the national land area. The semi-arid temperate grasslands in the northern China account for ~78% of the national grassland area (Chen and Wang, 2000). The Xilin River catchment in the eastern Inner Mongolia is located in the semi-arid area of the European–Asian mid-latitude grassland zone. The *Leymus chinensis* (*LC*) and *Stipa grandis* (*SG*) steppes, which account for about 60% of the Xilin River catchment (Li et al., 1988), are the dominant grassland types of the semi-arid grassland area in Inner Mongolia. Studies on N_2O emission and CH_4 uptake in the *LC* and *SG* steppes, therefore, are essential for understanding the roles of semi-arid temperate grasslands in global climate change. Du et al. (1997) and Wang et al. (1997) have preliminarily investigated N_2O emission and CH_4 uptake in this region with in situ measurements. Based on very limited flux data observed in the semi-arid grassland area of China, Chen et al. (2000) have very roughly estimated the annual total N_2O emission from Chinese grasslands as 112.13 Gg N, which is reasonably uncertain. So far, however, the strength of N_2O emission from and CH_4 uptake by the semi-arid grasslands and its variation mechanism has not been clear, yet. Further researches on these issues are still going on in the semi-arid grasslands of China. The objectives of this paper are to investigate (1) the diurnal and seasonal variations of N_2O emission from and CH_4 uptake by the semi-arid Inner Mongolian grasslands of China and (2) the effects of environmental regulating factors (soil temperature and soil moisture) and management practice (grazing).

2. Methods

2.1. Experimental sites

The experimental sites are in the Xilin River catchment (43°26′–44°39′ N, 115°32′–117°12′ E) and located in the vicinity of the Inner Mongolian Grassland Ecosystem Research Station (IMGERS), Chinese Ecosystem Research Network (CERN).

The experimental area is under a temperate terrestrial monsoon climate, with a frost-free period of 90–110 days. The annual mean air temperature is −1.5 to 2.5 °C in the past two decades, with the maximum monthly mean of 19 °C in July and the minimum of −21 °C in January. The annual precipitation of this region greatly varies from 180 to 500 mm, with a multi-year mean of about 350 mm (Chen, 1988). The annual precipitation distributes unevenly among seasons, with 60–80% falling in June to August (Chen, 1988).

The experimental fields are set in the *LC* and the *SG* steppes, which are the two dominant grassland types in the Xilin River catchment. Two field treatments for the *LC* steppe, i.e. ungrazed and moderately grazed, and one field treatment for the *SG* steppe, i.e. ungrazed, are applied in this study. A 25-ha *LC* steppe area, where the sampling plots for the ungrazed *LC* steppe were located, was fenced in 1979 and since then grazing has been forbidden in this fenced field. The surrounding area outside the ungrazed *LC* steppe, where the sampling plots of the moderately grazed *LC* steppe were located, has been grazed in the past decades. About 5 km away from the experimental *LC* steppe in the western direction is the experimental field of the *SG* steppe. A 25-ha *SG* steppe area, where the sampling plots for the ungrazed *SG* steppe were located, was also fenced in 1979 and since then grazing has been forbidden in this fenced field.

The location, altitude, climate, type and properties of the soil for each field treatment are given in detail in Table 1.

2.2. Sample collection and analysis

The fluxes of N_2O emission and CH_4 uptake were measured using static chamber and gas chromatography (GC) based techniques (Wang and Wang, 2003). Three replicate plots, which were set up by random, were simultaneously observed for each field treatment. The walls of sampling chambers were made of poly-methyl methacrylate and fixed up with frames of stainless steel. Each chamber, with a size of length × width × height = $40\times40\times35$ cm^3, was equipped with three probes for measuring the temperatures of soil (10 cm depth), earth surface and headspace air while the gas samples were taken from the enclosure. A 10-cm diameter ventilator, which was driven with a 12-V direct currency, was installed on a wall inside each chamber to make turbulence in the enclosure. Four air samples were collected with 100-ml plastic syringes during each 1-h enclosure, at an interval of 20 min. The samples were stored in the syringes equipped with gas-tight stoppers for a few hours before they were analyzed with the GC installed in the laboratory of IMGERS-CERN. The GC configurations for analyzing the CH_4 and N_2O in the samples and the methods for calculating the fluxes of N_2O emission and CH_4 uptake were completely the same as those described by Wang and Wang (2003). The flux