CO_2, CH_4, and N_2O Fluxes in a Larch Forest in Central Siberia as Affected by Urea Fertilizer

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1. INTRODUCTION

Boreal forest in Russia plays an important role in carbon storage (Rozhkov et al. 1996). Larch forest in central Siberia is characterized by low temperatures and precipitation, and the presence of continuous permafrost. Many studies of nutrient dynamics in the boreal forest in relation to the discontinuous presence or absence of permafrost have been conducted in North America and Europe (e.g., Nadelhoffer 2000), and N fertilization is known to change microbial activity in the soil (e.g., Homann et al. 2001). Preliminary study results show that nitrogen is a limiting factor for plant growth in boreal forests (Kondo et al. 2004). The purpose of this study was to elucidate the effect of urea fertilization on fluxes of the greenhouse gases CO_2, CH_4, and N_2O in a larch forest in central Siberia.

2. SITE AND METHODS

2.1 Study Site and N treatment

The study was conducted in Tura (64°19′N, 100°13′E), central Siberia, where the mean annual temperature and precipitation are –9.2 °C and 317 mm, respectively (Lydolph 1977). Soil type is Gelisol with poor drainage. The surface soil is frozen from mid-October to the beginning of May. The forest consists mainly of larch (*Larix gmelinii*) trees about 100 years old. Lichens and mosses 10 to 20 cm thick cover the forest floor. Control and N fertilization (+N) plots (15 m × 15 m) were established in the larch forest in 2004. In June and July 2004, June 2005, and August 2006, granular urea (total, 60 kg N ha^{-1} yr^{-1}) was used to fertilize the plots by hand.

2.2 Measurement of gas fluxes from the soil

Gas fluxes were measured by using a closed-chamber technique according to the method of Morishita et al. (2003). Before the gas flux measurement, green parts of the plants on the forest floor (mostly *Pleurozium schreberi*) were cut, and then the following day, gas fluxes were measured with 6 replications in the control and +N plots in June (before N was added), July (about 2 weeks after N was added), and September 2005, and in August (about 3 days after N was added) and September 2006. The gas fluxes were measured 2 or 3 times in a day. Soil temperature and moisture were measured at 10 cm and 0–12 cm soil depth, respectively, near the chambers. CO_2 was analyzed with a portable gas analyzer (LI–820, LICOR) in a house near the site. CH_4 (FID, Shimadzu GC-8A) and N_2O (ECD, Shimadzu GC-14B) were analyzed in Japan.

3. RESULTS

The highest and lowest soil temperatures were observed in July 2005 and September 2006, respectively (Fig. 1a). The mean soil temperature in the +N plots was significantly higher than that in the control plots in June 2005 and August and September 2006. The highest and lowest CO_2 fluxes were observed in July 2005 and September 2006, respectively (Fig. 1c). The CO_2 flux in the +N plot was significantly higher than that in the control plot at all measurement times. CH_4 tended to taken up by the soil, whereas N_2O tended to be emitted from the soil. There were no significant differences in CH_4 or N_2O fluxes between the treatments (Fig. 1d and e). The CO_2 flux was positively correlated with soil temperature in both plots (Fig. 2a), but the range of CO_2 fluxes at similar soil temperatures was larger in the +N plot than in the control plot. Neither the CH_4 nor the N_2O flux was correlated with soil temperature or moisture (Fig. 2c–f).

4. DISCUSSION

The CO_2 flux was significantly higher in the +N plot in all measurements (Fig. 1c), and the relationship between the CO_2 flux and soil temperature differed between plots (Fig. 2a). Urea fertilization was expected to promote root or microbial respiration. Though CO_2 is produced when urea is converted to ammonium, the CO_2 derived from urea was assumed very small (<1 mg C m^{-2} h^{-1}). Therefore, the results suggest that the increase in the CO_2 flux in the +N plot was due to an increase in root or microbial respiration. There were no significant differences in CH_4 and N_2O fluxes between the treatments (Fig. 1d, e). In many studies conducted in various ecosystems, addition of N (e.g., NH_4, NO_3) and urea decreases CH_4 uptake and increases N_2O emission from soils (e.g., Steudler et al. 1989). Kondo et al. (2005) reported strong immobilization of N, possibly due to nutrient poor conditions, in +N plots at the same site as this study site. N_2O is produced by both nitrification and denitrification, and the observed inhibition of CH_4 uptake may be related to nitrification (e.g., Steudler et al. 1989). Therefore, neither a clear decrease in CH_4 uptake nor an increase in N_2O emission was observed.

5. ACKNOWLEDGMENTS

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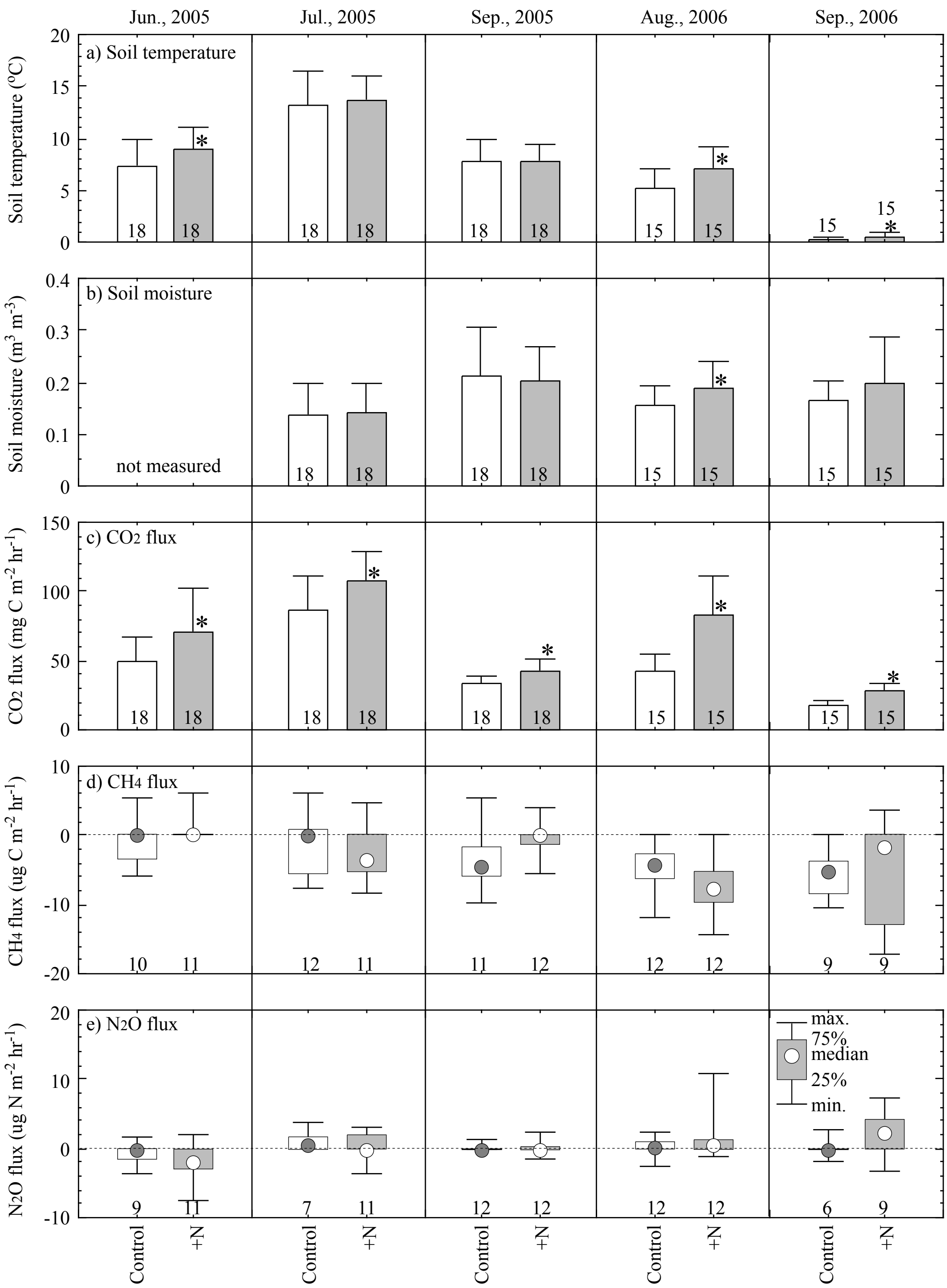

Fig. 1. Seasonal changes in a) soil tempereture, b) moisture, c) CO_2 flux, d) CH_4 flux, and e) N_2O flux in control and N fertilization (60 kg N ha^{-1} yr^{-1}) plots. Error bars in a), b), and c) denote the standard deviasion. The sample sizes (n) are shown below each column. *Significant difference ($p < 0.05$) between treatments.

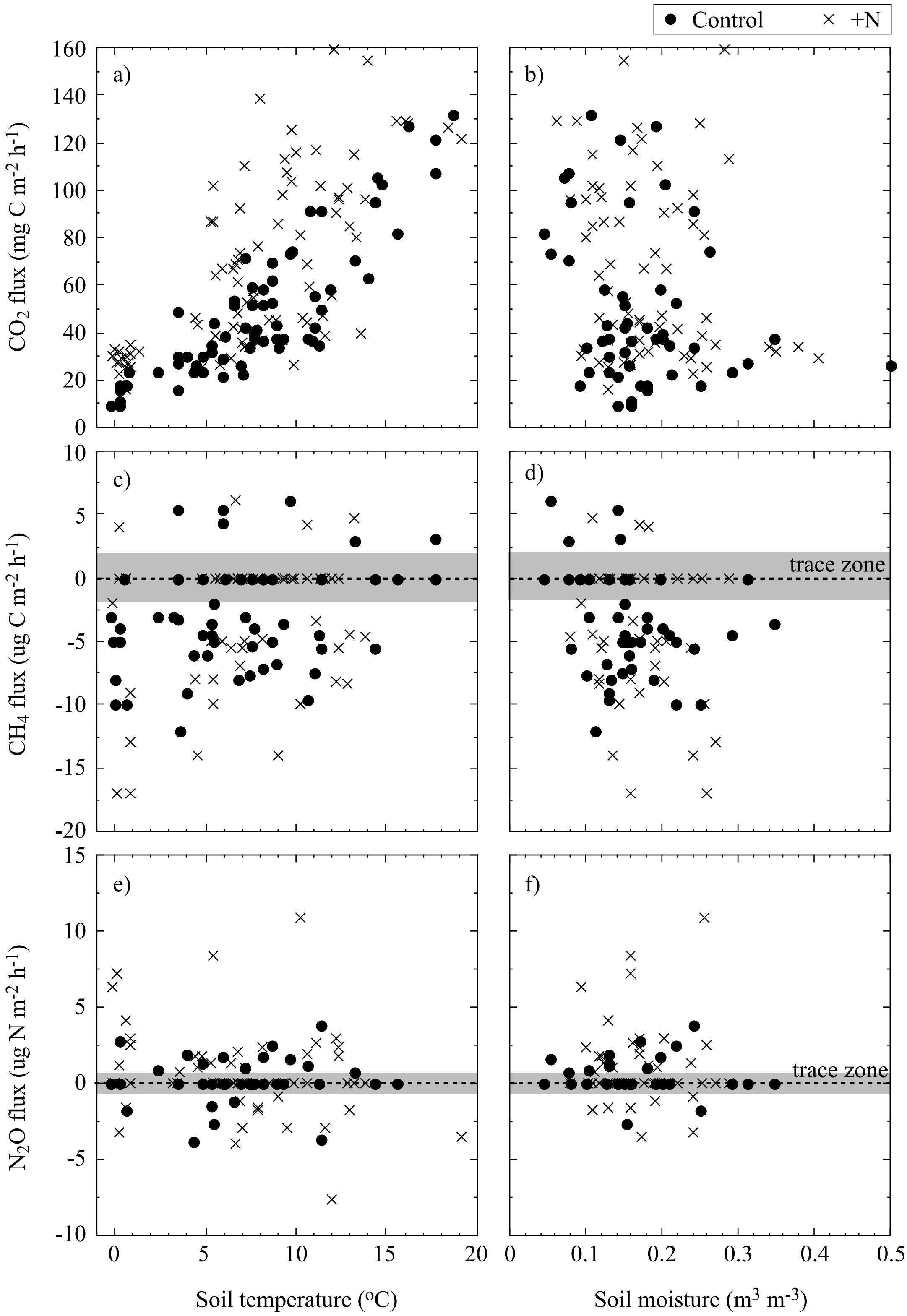

Fig. 2. Relationships between CO_2 flux and a) soil temperature and b) soil moisture; CH_4 flux and c) soil tempereture and d) soil moisture; and N_2O flux and e) soil temperature and f) soil moisture. The gray shading in the CH_4 and N_2O fluxe plots indicates trace values.