FLUXES OF CO_2, N_2O, AND CH_4 IN A COLD-TEMPERATE GRASSLAND SOIL OF NORTHERN JAPAN ESTIMATED BY ^{222}RN CALIBRATION METHOD AND STATIC CHAMBER METHOD

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ABSTRACT

Concentrations of ^{222}Rn, CO_2, N_2O and CH_4 were measured in a cold-temperate northern Japanese grassland soil during 1996 to compare the fluxes of CO_2, N_2O and CH_4 calculated by the ^{222}Rn method and the static chamber method and to estimate the source strengths of CO_2 and N_2O in the soil using the ^{222}Rn method. The ^{222}Rn fluxes ranged from 890 to 3400 dpm/m^2/h and the average was 1570±310 dpm/m^2/h on sandy soil (50% sand). The results of CO_2, N_2O and CH_4 flux-measurements by the ^{222}Rn method were in agreement with those by the static chamber method within the observed range of error. The vertical profiles of soil source strengths of CO_2 and N_2O were also calculated from the concentration gradients of ^{222}Rn, CO_2 and N_2O to investigate seasonal changes in the soil production rates of CO_2 and N_2O. The production rates of CO_2 and N_2O varied significantly by season, averaging 1650±450 mgC/m^3/h and 19±3.2 μgN/m^3/h, respectively. These seasonal changes in the source strengths of CO_2 and N_2O in the surface soil corresponded with changes in fluxes of CO_2 and N_2O from the soil.

INTRODUCTION

The gas transport in the soil is examined using the radioactive noble gas ^{222}Rn (half-life: 3.82 d), which is produced by α-decay of ^{226}Ra (half-life: 1602 y), as a tracer of all soil according to the method used by *Dörr and Münnich* (1987; 1990) and *Dueñas et al.* (1999). The ^{222}Rn method requires a lot of labor compared to the static chamber method, because of the necessity of measuring both depth profiles of the ^{222}Rn and other trace gases in the soil and ^{222}Rn flux at the soil surface. However, the ^{222}Rn method gives additional information about the trace gas diffusion in the soil. The ^{222}Rn flux at the soil surface and the ^{222}Rn concentration in soil air are influenced only by soil characteristics such as moisture content, tortuosity, and porosity, which can be determined by measuring the ^{222}Rn flux and concentration gradient at the same site. In this study, we used both the static chamber method and ^{222}Rn method to measure the fluxes of CO_2, N_2O and CH_4 from the soil. The differences between fluxes of CO_2, N_2O and CH_4 measured by two methods, seasonal variations of ^{222}Rn flux, and depth profiles of ^{222}Rn flux and these trace gases in the soil were discussed. The vertical profiles of CO_2 and N_2O source strengths were also estimated from the ^{222}Rn measurements to investigate seasonal changes in soil source strengths of CO_2 and N_2O.

RESULTS AND DISCUSSION

The ^{222}Rn method used to calculate fluxes of CO_2, N_2O, and CH_4 was modified from those of *Dörr and Münnich* (1987; 1990) and *Dueñas et al.* (1999). The diffusion transport of four gases, ^{222}Rn, CO_2, CH_4, and N_2O, in unsaturated soil zone are described by Fick's law. The fluxes of CO_2, N_2O, and CH_4 calculated by the ^{222}Rn method were compared with those estimated by the chamber method on grassland soil. A one-way ANOVA revealed that the differences between the two methods were not significant ($p<0.05$). The comparisons of CO_2, N_2O, and CH_4 fluxes by two methods, calculated diffusion coefficients and relaxation depths of CO_2, N_2O, and CH_4 were shown in Table 1. The temporal variations of CO_2, N_2O, and CH_4 by two methods may be related to variations in many factors such as soil microbial activity, soil moisture contents, soil temperature, soil structure/grain size and so on. The results of the point measurements of CO_2, N_2O, and CH_4 fluxes could be atypical due to the heterogeneity. To accurately estimate the fluxes of CO_2, N_2O, and CH_4 in heterogeneous systems, multiple CO_2, N_2O, and CH_4 flux-measurements are needed to cover the target area widely. The chamber method is thus a useful procedure to evaluate temporal heterogeneity.

Source strengths of CO_2 and N_2O at each depth were calculated with the measured CO_2 and N_2O concentration profiles and estimated CO_2 and N_2O diffusion coefficients were calculated from results of the ^{222}Rn method. Until now, it has been difficult to quantitatively assess soil source strength profiles of CO_2 and N_2O because of uncertainties associated with measurements of physical soil properties such as soil moisture contents, tortuosity, and total porosity. The chamber method gives only flux information; however, the ^{222}Rn method gives the fluxes of CO_2, CH_4 and N_2O and the source strengths of CO_2 and N_2O, simultaneously, without disrupting the soil profile. Knowledge of the soil strengths of CO_2 and N_2O are significant for understanding the vertical distribution and seasonal variability of microbial decomposition / root respiration and nitrification/denitrification in the soil.

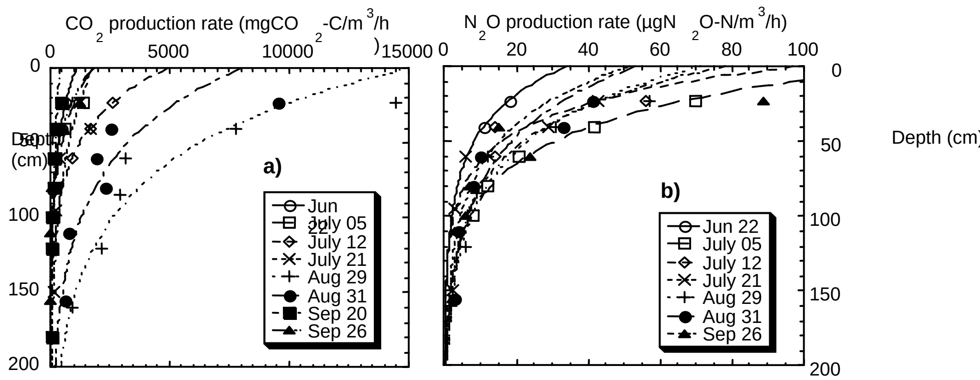

Fig. 1. The source strengths of a) CO_2 and b) N_2O in upper soil (>50 cm) using the ^{222}Rn method were exhibited significant seasonality from June to September, 1996 (R>0.86).

Table 1. Calculated diffusion coefficients, relaxation depths, and fluxes of CO_2, N_2O and CH_4 by the ^{222}Rn method and by the chamber method in grassland aerated soil, northern Japan, during 1996

Date	Diffusion coefficients (cm^2/s)			Relaxation depth (cm)			^{222}Rn Flux	CO_2 Flux	N_2O Flux	CH_4 Flux	CO_2 Flux*	N_2O Flux*	CH_4 Flux*
in 1996	CO_2	N_2O	CH_4	CO_2	N_2O	CH_4	(dpm/m²/h)	(mgC/m²/h)	(μgN/m²/h)	(μgC/m²/h)	(mgC/m²/h)	(μgN/m²/h)	(μgC/m²/h)
06-22	0.043	0.016	0.047	143	87	149	918	43.3	7.64	-10.6	34.2	6.81	-8.88
07-05	0.078	0.032	0.062	193	123	172	1242	16.9	4.54	-2.01	17.5	5.21	-3.55
07-12	0.055	0.022	0.067	162	102	178	1570	36.2	3.91	-8.42	22.1	9.35	-7.10
07-21	0.078	0.046	0.083	193	148	199	2269	46.1	4.36	-6.62	55.1	6.42	-7.77
08-29	0.086	0.041	0.073	202	140	186	3404	73.5	2.72	-3.05	65.3	4.28	-2.58
08-31	0.046	0.026	0.066	148	111	177	1269	49.6	2.47	-4.57	41.1	3.55	-5.11
09-20	0.043	N.M.	0.075	143	N.M.	189	975	40.1	N.M.	-17.6	45.5	4.25	-12.2
09-26	0.035	0.019	0.045	129	95	146	894	19.8	7.65	-6.82	21.0	8.65	-7.89

N.M. indicates not measured.

* denotes the each flux measured by the chamber method.

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