P1.12 THE TEMPORAL FLUCTUATIONS IN SOIL RESPIRATION WHEN PRECIPITATION IS INTERCEPTED ABOVE THE FOREST FLOOR

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1. INTRODUCTION

The simple transfer of CO_2 from forest soil to the atmosphere is one of the most important processes in the carbon cycle of forest communities. Several studies have modeled the CO_2 flux at the forest floor (Koizumi *et al*., 1999; Davidson *et al*., 2000), but many unknowns remain, because CO_2 has numerous sources, including litter, soil organic matter, soil organisms, and roots. Moreover, several factors and soil characteristics affect each source in different ways. Koizumi *et al*. (1999) used soil temperatures and soil moisture data to model the forest-floor CO_2 flux. However, these parameters can change over short periods and small distances. Both soil respiration monitoring and experimental observations are necessary to clarify the process of soil respiration. Therefore, we observed soil respiration from the forest floor where precipitation was intercepted in a deciduous secondary forest in Japan using an automated chamber system. The interception of the precipitation above the soil prevented penetration of soil water into the soil, resulting in extremely dry shallow soil. The experiment examined the effect of soil moisture in the shallow layer on soil respiration.

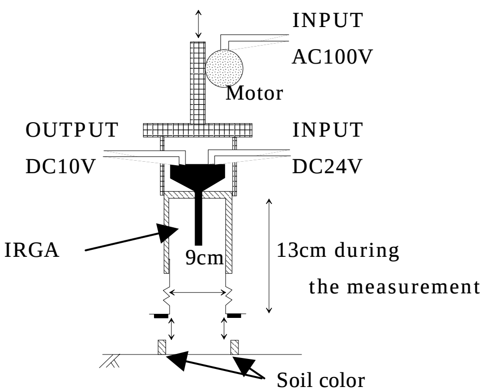
2. METHODOLOGY

We developed an instrument that automatically raises and lowers a soil chamber, shown in Fig. 1. The infiltration of precipitation into the soil was prevented by acrylic boards around the chamber system, resulting in extremely dry shallow soil. The chamber contained an infrared gas analyzer (IRGA) sensor (VAISALA, GMD20) to measure the CO_2 concentration. The forest floor CO_2 flux (F_c) was calculated from Eq.(1) using the measured increase in the CO_2 concentration in the chamber over time.

$$F_c = r\, V/A\, D_c/D_t\, 273/(T + 273) \qquad (1)$$

where r is the CO_2 gas density (1.96 kg m^{-3}), V is the chamber volume, A is the section area of the chamber, D_c/D_t is the rate of increase in the CO_2 concentration, and T is the air temperature.

In this study, one measurement cycle consisted of a 25-min measuring period and a 5-min rest period. The chamber was lowered to the soil during the measuring period, and the



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CO_2 then raised during the rest period. In Eq.(1), D_c/D_t represents the difference in the gas concentrations measured at 5 and 20 min after the start of each measuring period. Nobuhiro *et al*. (2003) verified the usefulness of enclosing an IRGA in a soil chamber and determined that the flux rates measured using this chamber method almost equaled those measured by the closed-flow method with an LI-800 (Li-COR), over a wide range. The automated chamber was placed on a ridge. The soil temperature and volumetric water content ratio were measured at depths of 5 and 20 cm where precipitation could reach the forest floor with temperature probes (Campbell, Model 107) and a TDR sensor (Campbell, Model CS615), respectively. Evergreen trees (*Eurya japonica* Thunb.), 10 cm in diameter at breast height, grew 1.5 m from the automated chamber. The observation period was from May 31 to July 17, 2001.

3. SITE DESCRIPTION

The study was conducted in the Yamashiro Experimental Basin (34º47'N, 135º51'E), which is located in the southern part of Kyoto Pref., Japan. The forest consisted of deciduous species (basal area: 13.31 m^2 ha^{-1}), such as *Quercus serrata*, and evergreen species (basal area: 6.29 m^2 ha^{-1}), such as *Ilex pedunculosa*. The forests in the Yamashiro area were harvested in the 8th and 9th centuries, and little vegetation grew there until approximately 120 years ago, when plantations were established; litter was collected for fuel and fertilizer until about 40 years ago. Consequently, the forest soil in the Yamashiro area contains very little organic matter. The soil originated from granite and has been classified as an immature brown forest soil with a poorly developed layer structure (Araki *et al*., 1997). The amount of litter in the basin was measured and was approximately 400g m^{-2}.

4. RESULTS AND DISCUSSION

4.1 Daily Fluctuation in the CO_2 Flux

Fig. 2 shows the daily fluctuation in F_c from June 4 to 12, 2001. Precipitation occurred on June 6. Until the precipitation event, F_c showed a typical diurnal fluctuation with a maximum (0.05 mg s^{-1} m^{-2}) at night and a minimum in the day. After the precipitation event, F_c jumped to 0.06 mg s^{-1} m^{-2}. Davidson *et al*. (2000) and Koizumi *et al*. (1999) also reported an abrupt increase in F_c after precipitation. No diurnal variation was observed between June 6 and 10, when the variation again became evident. The daily fluctuation in F_c seemed to correspond better to the temperature of the soil at a depth of 20 cm (T_{20}) than to that at a depth of 5 cm (T_5), except on days immediately following precipitation events.

4.2 Relationship of Daily Fluctuation

The daily fluctuations in T_5, T_{20}, and F_c were standardized using Eqs.(2) and (3), and the root mean square error was calculated with Eq.(4) to quantify the relationship.

$$\mathrm{ST}(T_i) = (T_i - \mathrm{MIN}(T_i))/(\mathrm{MAX}(T_i) - \mathrm{MIN}(F_c)) \quad (2)$$

$$\mathrm{ST}(F_c) = (F_c - \mathrm{MIN}(F_c))/(\mathrm{MAX}(F_c) - \mathrm{MIN}(F_c)) \quad (3)$$

where ST is the standardized value of T_5, T_{20}, or F_c (the subscript i indicates the measurement depth), and MAX and MIN are the daily maximum and minimum values of T_5, T_{20}, or F_c.

$$\mathrm{RMSE}(T_i) = ((\Sigma(\mathrm{ST}(F_c) - \mathrm{ST}(T_i))^2)/N)^{0.5} \quad (4)$$

where RMSE is the root mean square error between T_5, T_{20}, and F_c, and N is the number of data. For this study, the calculations were based on measurements at 30-min intervals over a period of one day (N = 48). RMSE(T_{20}) was usually smaller than RMSE(T_5) (Fig. 3), indicating that the daily fluctuation in F_c corresponded more closely to the soil temperature in the deep layer than to that in the shallow layer. Generally, F_c is larger when the soil temperature is higher (Davidson *et al*., 2000).

Therefore, we hypothesize that the observed fluctuation in F_c was governed by CO_2 evolving from deep-soil biological processes, such as root respiration. When the shallow soil layer is dry, only small amounts of CO_2 originate from litter and organic matter decomposition in the shallow soil layer. The shallow soil must have been extremely dry due to the interception of precipitation by the chamber system.

4.3 Precipitation Effect on the CO_2 Flux

RMSE(T_{20}) was usually smaller than RMSE(T_5). However, RMSE(T_{20}) increased as much as RMSE(T_5) after precipitation events. For example, the value of RMSE(T_{20}) was larger than 0.4 between June 6 and 10 when there was no diurnal fluctuation in F_c and decreased to 0.25-0.30 afterward. Therefore, a small RMSE(T_{20}) indicates the appearance of a diurnal fluctuation in F_c in this study. Generally, the CO_2 flux at the forest floor is larger when the soil is wetter (Davidson *et al*., 2000), suggesting that when the shallow soil layer becomes wet, CO_2 evolution increases, and consequently RMSE(T_{20}) increases after precipitation. However, the cover kept the shallow soil extremely dry. The low soil moisture content ratio means that there is a large gaseous phase in the soil and a high diffusive coefficient. CO_2 gas can diffuse more easily in the soil under the cover than elsewhere. CO_2 gas was thought to advect from the surrounding area into the covered soil. Consequently, the diurnal fluctuation in F_c disappeared because CO_2 originated from both the shallow uncovered soil and the deep covered soil. This is consistent with the increase in the F_c after precipitation events (Fig. 2). However, no clear relation between RMSE(T_{20}), which suggests the appearance of a daily F_c fluctuation, and θ_5 was seen in Fig. 4, which shows their relation over several days after precipitation events. Generally both RMSE(T_{20}) and θ_5 decreased after precipitation events. Therefore, the points in Fig. 4 move from the upper-right to the lower-left with time. In addition, the points moved down in the left and right parts of the graph in early and later May, respectively. This was because the observation period included the rainy season, when the overall soil moisture tends to increase. Nevertheless, the shallower soil layer dried more quickly (Fig. 2). The litter layer is thought to dry in the days immediately following precipitation events. Tamai (2000) reported that the evaporation rate from the forest floor in the Yamashiro basin was 0.4 to 0.8 mm day^{-1} on days immediately following precipitation, and it decreased to 0.3 mm day^{-1} on subsequent days; this drop in the evaporation rate was attributed to the drying of litter. This is consistent with the observed increase in CO_2 evolution from the litter layer and with the disappearance of the diurnal variation in F_c following precipitation events. The observations in Yamashiro forest suggest the importance of soil moisture in the shallow layer to soil respiration.

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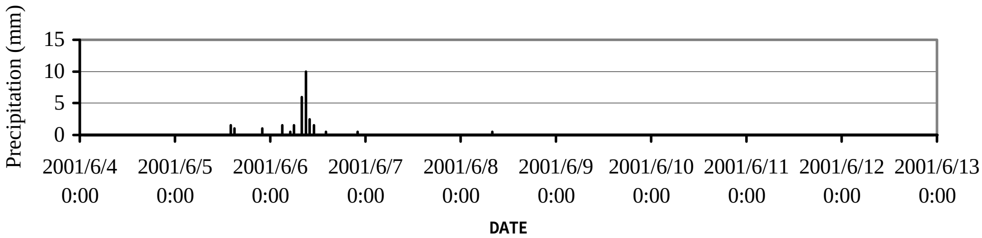
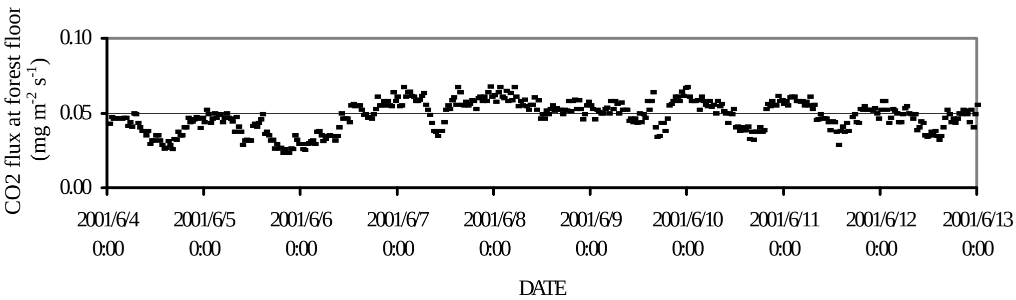
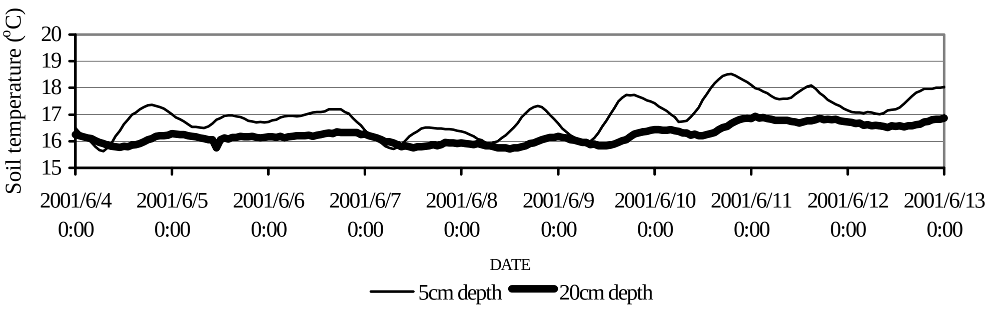


(a) Precipitation



(b) CO_2 flux



(c) Soil temperature

Fig.-2. The fluctuation of CO_2 flux at the forest floor around the natural precipitation.

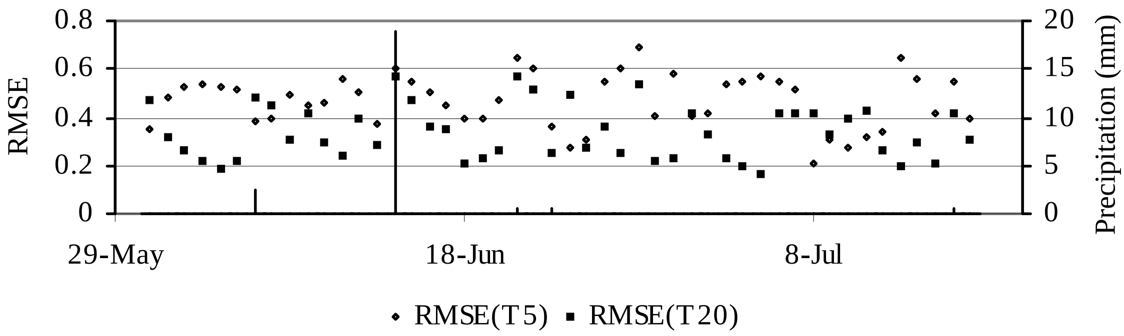


Fig. 3 Comparioson between RMSE(T_5) and RMSE(T_{20})

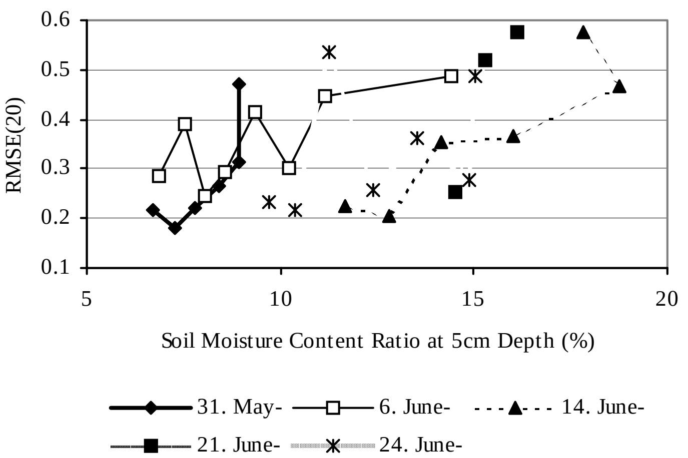


Fig.4 The relation between RMSE(T_{20}) and soil moisture at 5cm depth after the precipitation event