Effects of Temperature and Moisture on Soil Respiration in a Larch Forest in Central Siberia

[1]Tomoaki MORISHITA, [1]Yojiro MATSUURA, [2]Olga A. ZYRYANOVA, and [2]Anatoly P. ABAIMOV

[1]Forestry and Forest Products Research Institute, Tsukuba, Japan
[2]V.N. Sukachev Institute of Forest, Siberian Branch, Krasnoyarsk, Russia

1. INTRODUCTION

Soil is the major carbon pool in terrestrial ecosystems (Schlesinger and Andrews, 2000). Soil respiration (SR) is an important component process (Schlesinger and Andrews, 2000) of carbon cycle. SR is positively related to soil temperature in northern hemisphere temperate ecosystems (eg. Hibbard et al., 2005). SR is also affected by soil moisture; very high soil moisture can block soil pores (Bouma and Bryla, 2000) and very low soil moisture limits microbial and root respiration (Yuste et al., 2003). But, in some cases, SR is not related to soil moisture (eg. Palmroth et al., 2005).

Boreal forest in Russia plays an important role in carbon storage (Rozhkov et al., 1996). Larch forest in Central Siberia was characterized by low temperature and precipitation, and the presence of permafrost. Furthermore, the ground surface was characterized by low earth hummock microtopography with various lichens and mosses. So, it is considered that both soil temperature and soil moisture are very important controller of soil respiration in the region. The purpose of this study was to elucidate the effect of soil temperature and moisture on the SR related to the difference of forest floor vegetation in a larch forest in Central Siberia.

2. SITE AND METHODS

2.1 Study Site

The study was conducted in Tura (64° 12' N, 100° 27' E), Central Siberia at the beginning of June, middle of July, and beginning of September in 2005. The annual mean temperature and precipitation are –9.2 °C and 334 mm, respectively (Robert, 1997). Soil type is Gelisol with permafrost below the depth of 70 to 100 cm from the surface and poor drainage. The soil is frozen from mid– October to the beginning of May. The forest consists mainly of Larch (*Larix gmelinii*) trees about 100 years old. Patches of lichens and mosses, mainly *Cladina* sp., *Pleurozium* sp., and *Aulacomnium* sp., cover the forest floor with depth of 10 to 20 cm.

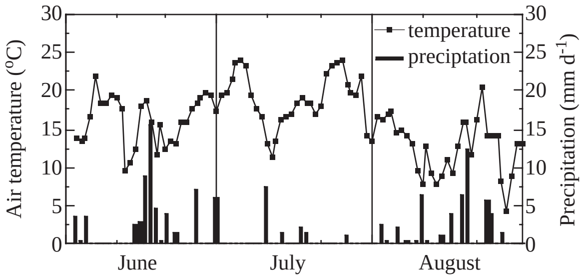

Fig. 1. Air temperature and daily precipitation in the site.

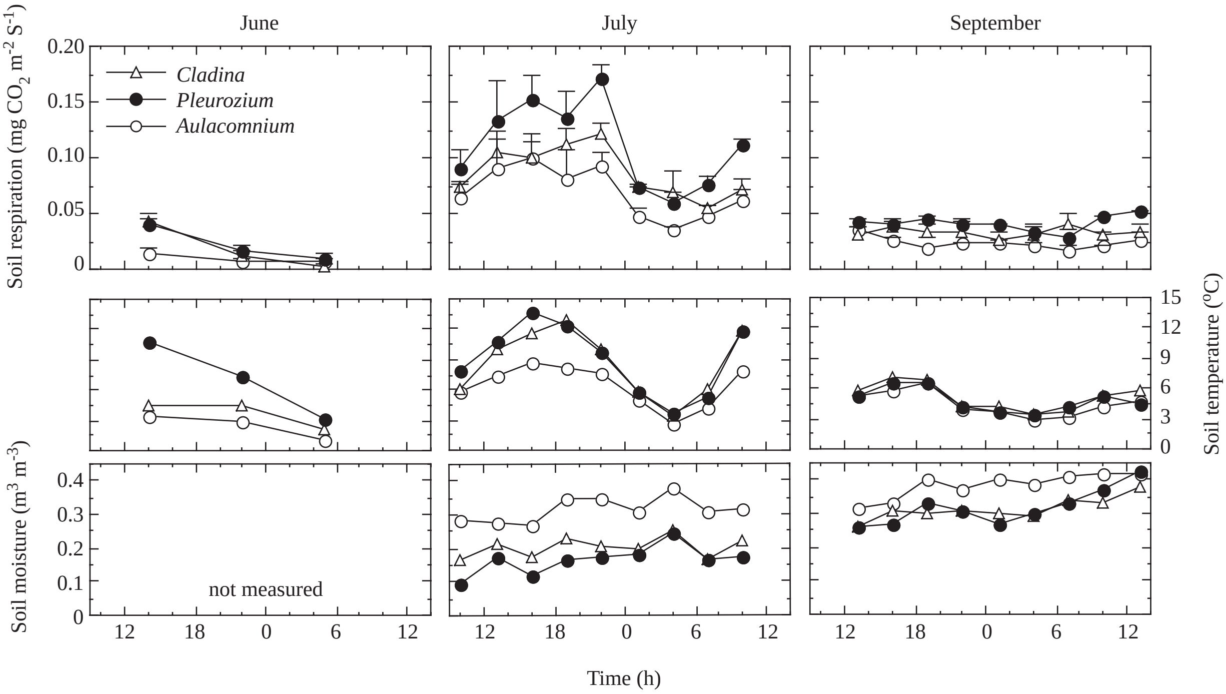

Fig. 2. Soil respiration in June, July, and September with soil temperature and moisture.

Table 1. Summary of soil respiration, soil temperature, and moisture.

	June		July			September		
	SR mg CO_2 m^{-2} S^{-1}	Temp. °C	SR mg CO_2 m^{-2} S^{-1}	Temp. °C	Moist. m^3 m^{-3}	SR mg CO_2 m^{-2} S^{-1}	Temp. °C	Moist. m^3 m^{-3}
Cladina	0.019 a	3.7 b	0.087 b	8.6 a	0.20 b	0.033 b	5.1 a	0.31 b
Pleurozium	0.022 a	7.1 a	0.112 a	9.0 a	0.17 b	0.041 a	4.9 a	0.31 b
Aulacomnium	0.010 b	2.5 b	0.069 c	6.4 b	0.31 a	0.023 c	4.4 b	0.38 a

different letters show a signifcant defference among the vegetetion at 5% level

2.1 Measurement of Soil Respiration rates

SR was measured by using a closed chamber technique according to the method of Sawamoto et al. (2000). Six stainless steel chambers, 25 cm height and 20 cm in diameter, were used. Each two chambers were set on patches of *Cladina stellaris*, *Pleurozium shreberi*, and *Aulacomnium palustre*.

Before the measurement of SR, green parts of plants on the forest floor were cut carefully in order to exclude plant respiration. And then, the chamber collars were installed at 5 cm depth into the soil and kept overnight to eliminate the disturbance. In the following day, each 500–mL gas sample was taken into a Tedlar® bag before the chamber lid was set up and at 6 minutes after the lid was set up. The SR was measured three times in June, and nine times in July and September in a day. Soil temperature and moisture as a volumetric water content moisture by TDR (Hydrosense™, Campbel Scientific Australia Phy. Ltd.) were measured at a depth of 10 cm and 0–12 cm below the surface near the chambers, respectively.

CO_2 concentrations in the bags were analyzed by portable gas analyzer (LI–820, LICOR). The SR was calculated according to the change in CO_2 concentrations in the chamber with time by using a linear regression law.

2.3 Statistical Analysis

Mean temperatures, soil moistures, and SR in each patch were calculated from 6 to 18 measurements. Two–way analysis of variance followed by Fisher's test was used to compare the means. Multiple regression analysis was conducted to explain the SR using soil temperature and moisture. The stepwise method was used for the calculation. Excel Toukei (SSRI, Japan) was used for all statistical analysis.

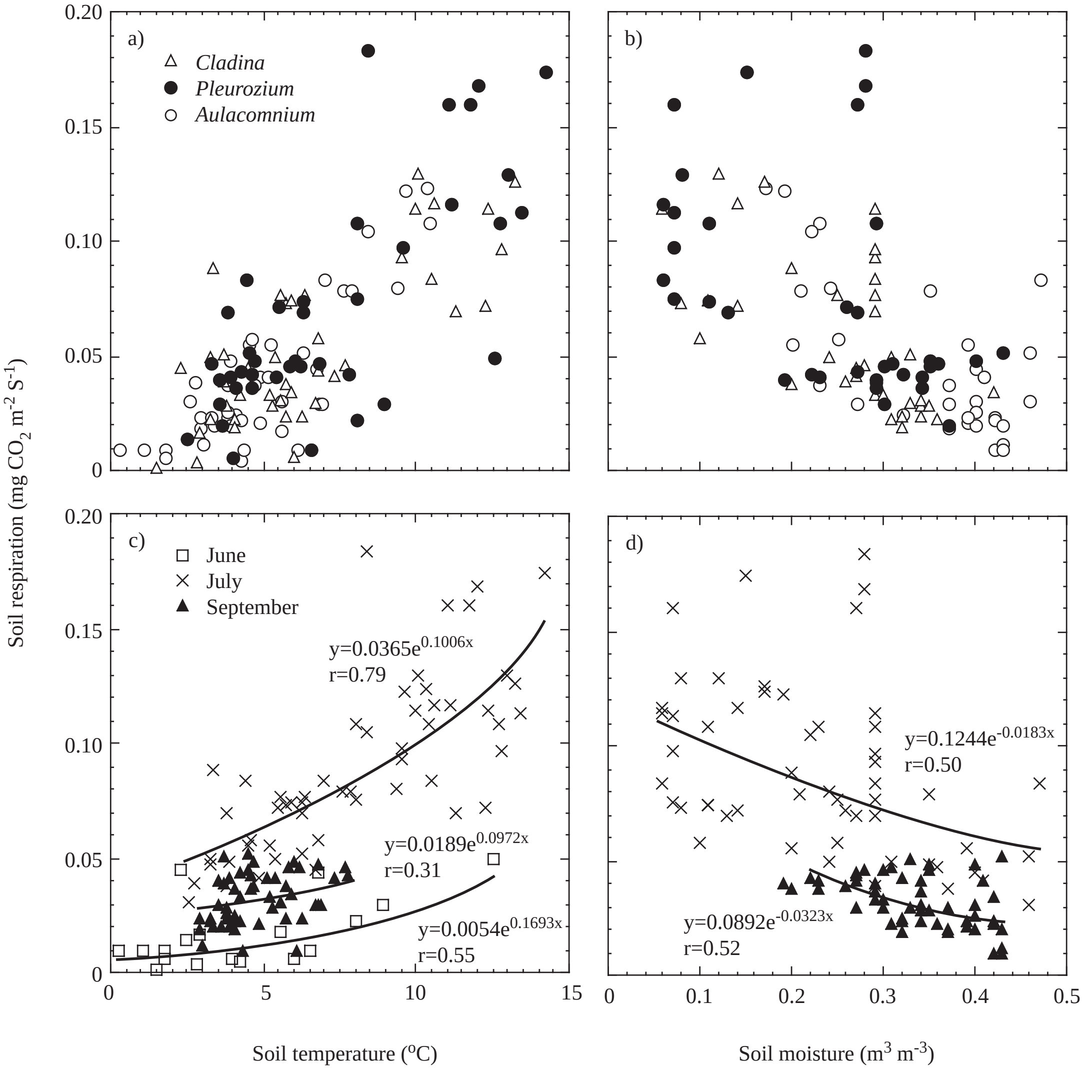

Fig. 3. Relationship between soil respiration and soil temperature/moisture.

3. RESULTS AND DISCUSSION

Daily mean air temperature and precipitation from June to August are shown in Fig. 1. Air temperature was relatively higher in July, but low temperature was observed in middle of July (min: 11.3 ^{o}C). Precipitation was smallest in July among three months.

Daily change and mean of soil temperature, moisture, and soil respiration are shown in Fig. 2 and Table 1, respectively. Soil temperatures in each patch were highest in July (max: 13.6 ^{o}C at *Pleurozium* site), but the soil temperature in night time decreased almost equal to that in June and September (Fig. 2). And soil temperature in the *Aulacomnium* patch was significantly lower than that in other patches in July (6.4 ^{o}C) and September (4.4 ^{o}C).

Soil moistures in each patch were higher in September than that in July (Fig. 2). Soil moisture in the *Aulacomnium* patch was significantly higher than that in other patches in both July (0.31 m^3 m^{-3}) and September (0.38 m^3 m^{-3}). Highest SR (mg CO_2 m^{-2} s^{-1}) was observed in *Pleurozium* patch in July (0.184). There were significant differences among the mean SR of different patches (Table 1). SR for each patch were in the following order: *Pleurozium* (0.112 ± 0.041 in July, 0.041 ± 0.007 in September) > *Cladina* (0.087 ± 0.024 in July, 0.0331 ± 0.009 in September) > *Aulacomnium* (0.069 ± 0.029 in July, 0.023 ± 0.008 in September). The values of the SR were lower than those previously reported 0.065–0.396 mg CO_2 m^{-2} s^{-1} for a larch forest in eastern Siberia measured in summer (Sawamoto et al., 2000).

The relationship between the SR and soil temperature or soil moisture is shown in Fig. 3. SR was positively correlated with soil temperature ($r=0.80$ $p<0.01$) (Fig. 3–a) and negatively correlated with soil moisture ($r=-0.61$ $p<0.01$) (Fig. 3–b). It is considered that SR in *Aulacomnium* patch was smaller than other patches due to low soil temperature and high soil moisture (Table 1). *Aulacomnium* patches were relatively lower microtpography. So that, rain and melted water could be gathered in the patch and prevented to gas diffusion and increase soil temperature. A multiple regression analysis indicated that SR could be derived by soil temperature (T) and moisture (M) as follows:

$$SR=0.00880(T)-0.0961(M)+0.0314$$
$$(R^2=0.69,\ n=106,\ P=2.1\times10^{-27})$$

According to standardized regression coefficient, the effect of soil temperature (0.66) on the SR was higher than that of soil moisture (–0.26). Low soil moisture limits microbial and root respiration (Yuste et al., 2003) and very high soil moisture prevent to release of CO_2 from the soil (Bouma and Bryla, 2000). In the study, it was suggested that increasing soil moisture decreased SR in spite of low precipitation.

The relationship between the SR and soil temperature (Fig. 3–c) or soil moisture (Fig. 3–d) is different among three measurement periods. SR includes soil microbial respiration and plant respiration (Raich and Schlesinger, 1992). Jiang et al. (2005) reported that root respiration is relatively higher in summer than that in spring and autumn, and Q_{10} values of SR and root respiration are different in a larch forest in northeastern China. The SR in this study might relatively lower in September than that in July due to a decrease in root respiration. So, it may be necessary to consider the Q_{10} of root respiration to improve the accuracy of the estimation of SR.

4.ACKNOWLEDGMENTS

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