CARBON BALANCE OF LARCH FOREST ECOSYSTEMS

N. Liang[1], Y. Fujinuma[2], and G. Inoue[3]

Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Ibaraki 305-8506, Japan; [1] liang@nies.go.jp; [2] fujinuma@nies.go.jp; [3] inouegen@nies.go.jp

ABSTRACT

We partitioned the components of CO_2 flux by the chamber approaches for a 45-year-old larch forest in northern Japan. In 2003, annual soil-CO_2 efflux was averaged to 9.59 tC ha^{-1}, heterotrophic respiration was about 5.47 tC ha^{-1} that accounted about 57% of the soil-CO_2 efflux, net annual CO_2 exchange of understory vegetation was about -0.39 tC ha^{-1}, annual aboveground woody tissue respiration was bout 0.75 tC ha^{-1}, and annual photosynthesis and respiration of the canopy was about -12.75 and 1.15 tC ha^{-1}, respectively. Annual GPP, NPP, NEP and ecosystem respiration for this forest was estimated to be about 13.49, 7.16, 2.04 and 11.45 tC ha^{-1}, respectively. The contribution of canopy respiration, aboveground woody respiration, root respiration and heterotrophic respiration to GPP was about 8.1%, 5.6%, 30.6% and 40.5%, respectively.

INTRODUCTION

Larch forests widely distribute throughout the North Hemisphere, e.g. occupying >40% of Russian forests, thus is global important of forested biome. However, the carbon budget of larch ecosystems has received little attention. We partitioned the components of the CO_2 flux with the chamber methods, in terms of canopy photosynthesis, aboveground woody tissue respiration, understory vegetation gas exchange, total soil-CO_2 efflux, heterotrophic and root respirations. Our objectives were: (1) quantify the contributions of CO_2 flux components to GPP; and (2) evaluate the influence of environmental conditions on CO_2 flux components.

MATERIALS AND METHODS

The chamber measurements were carried out from 2001 in a 45-year-old Japanese larch (*Larix kaempferi* Sarg.) plantation (42°44'N, 141°31'E) with canopy height of about 15 m in Hokkaido, Japan. The forest understory was densely covered by perennial buckler fern (*Dryopteris crassirhizoma*). Mean annual precipitation is approximately 1250 mm; and mean annual temperature is 7.3 °C. The soil is homogeneous, well-drained, arenaceous, and developed from volcaniclastic sediment [*Liang, et al.*, 2004].

Canopy photosynthesis/respiration was continuously measured by a 24-automated-chamber system described by [*Liang, et al.*, 2005a, c]. Stem and branch respiration was measured by a 24-automated-chamber system according to *Liang, et al.* [2005b]. The understory carbon budget was measured by a 24-automated-chamber system, i.e., 8 chambers for soil-CO_2 efflux, 8 chambers for heterotrophic respiration, and 8 chambers for photosynthesis/respiration of understory vegetation [*Liang, et al.*, 2003; *Liang, et al.*, 2004].

RESULTS AND DISCUSSION

Carbon budget in the forest understory

Seasonal change patterns of soil-CO_2 efflux, heterotrophic respiration and the sum of soil-CO_2 efflux and undergrowth gas exchange were shown in Fig. 1a. In 2003, annual soil CO_2 efflux was estimated to be about 9.6 tC ha^{-1}. Result matches averaged annual soil CO_2 efflux for temperate forests [*Liang et al*., 2004]. Annual heterotrophic respiration was about 5.5 tC ha^{-1}, contributing about 57% of total soil-CO_2 efflux. The net exchange of CO_2 (NPP) by the understorey was about -0.39 tC ha^{-1} (Fig. 1a). We found that variation in soil-CO_2 efflux depended strongly on soil temperature at 5-cm depth. The Q_{10} quotient was 3.1 and 3.5 for total soil-CO_2 efflux and heterotrophic respiration, respectively. However, we did not find any correlation ($r < 0.20$, $p > 0.1$) between soil efflux and soil moisture. Abundant precipitation at this forest, coupled with good soil drainage, resulted in a volumetric soil moisture, usually 30-40%, that was uniformly favorable to microbial activity and root respiration throughout the whole seasons [*Liang et al.*, 2004].

CO_2 efflux from the aboveground woody tissue

Daily wood CO_2 efflux showed clear seasonal change, with lower value in the non-growing season and higher value in the grow season on both surface area basis and wood volume basis. During the summer (between June 15 and September 15), mean CO_2 efflux rate at stem height of 2.9 m was about 0.7 μmol m^{-2} s^{-1}, similar to those reported for other temperate deciduous species [reviewed by Liang et al., 2005b]. However, efflux rate increased significantly ($p < 0.001$) at stem height of 9.1 m with value of about 1.1 μmol m^{-2} s^{-1}. Efflux rate for branches at 12 m high showed the highest value of 1.3 μmol m^{-2} s^{-1}. Stand level aboveground wood CO_2 efflux was estimated to be about 0.75 and 0.74 tC ha^{-1} yr^{-1} on wood and sapwood volume basis, respectively. We found strong response in wood CO_2 efflux to wood temperature at all three measurement locations. Throughout the whole year, Q_{10} was average to 4.7 for the wood at 2.9 m high. However, Q_{10} increased to 5.1 and 5.5 at stem height of 9.1 and 12 m, respectively.

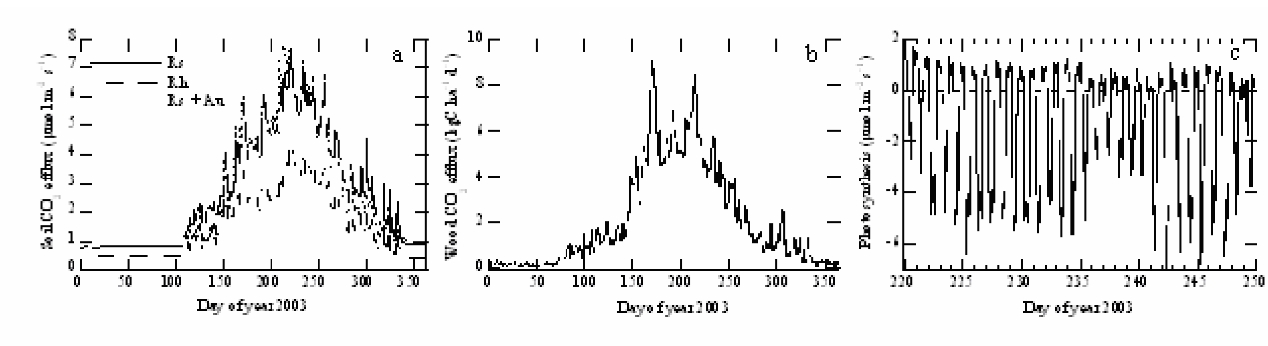

Fig. 1. Seasonal changes in total soil CO_2 efflux (R_s), heterotrophic respiration (R_h) and sum of R_s and undergrowth gas exchange (A_u) (a), woody tissue respiration (b), and canopy photosynthesis (c) for Tomakomai larch forest in 2003.

Canopy photosynthesis

Fig. 1c shows diurnal and seasonal changes in hourly mean net photosynthetic rate for the 24 chambers. Canopy photosynthesis showed a typical light response curve [*Liang et al.*, 2005a, c]. Light saturated photosynthetic rate reached to 4.5 ± 1.2 μmol m^{-2} s^{-1} that usually occurred with highest irradiances. Photosynthetic light use efficiency was about 0.021, consisting with previous reports for most tree species. Mean nighttime respiration rate was 0.6 ± 0.4 μmol m^{-2} s^{-1}, and showed typical exponential correlation with the air temperature. Q_{10} of respiration is 7.5; the value is significant higher than previous reports for the tree species by periodical measurements with other chamber systems. Annual photosynthesis and respiration of canopy foliage was estimated to be about -12.75 and 1.15 tC ha^{-1}, respectively, based on the chamber measurements and canopy structure (foliage biomass).

CONCLUSION

Whole ecosystem respiration was about 11.5 tC ha^{-1} yr^{-1} based on the scale up from the chamber measurements. The contribution of each flux components to total ecosystem respiration was about 10.0, 6.5, 35.9 and 47.6% by the canopy foliage, aboveground woody tissue, roots and soil microbes, respectively. Therefore, soil CO_2 efflux was the largest component (83.5%) of ecosystem respiration. Moreover, during the non-growing season, the contribution of soil efflux to ecosystem respiration could reach to 95.5%. Stand level aboveground wood respiration was about 0.75 and 0.74 tC ha^{-1} yr^{-1} on wood and sapwood volume basis, respectively. Annual canopy photosynthesis and respiration was estimated to be about -12.75 and 1.15 tC ha^{-1}, respectively.

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