ESTIMATING THE CO_2 FLUX FROM COARSE WOODY DEBRIS USING AUTOMATED AND MANUAL CHAMBER MEASUREMENTS IN A TEMPERATE DECIDUOUS BROAD-LEAVED FOREST IN JAPAN

M. Jomura[1], Y. Kominami[2], K. Tamai[3], T. Miyama[2], Y. Goto[2], M Dannoura[1], and Y. Kanazawa[1]

[1]*Graduate School of Science and Technology, Kobe University 1-1, Rokkodai-cho, Nada-ku, Kobe, Hyogo, 657-8501, Japan; majomura@mbox.kyoto-inet.or.jp*
[2]*Kansai Research Center, Forestry & Forest Products Research Institute, Kyoto 612-0855 Japan*
[3]*Kyusyui Research Center, Forestry & Forest Products Research Institute, Kumamoto 862-0862, Japan*

ABSTRACT

The CO_2 flux from coarse woody debris (R_{CWD}) in a deciduous broad-leaved forest was measured using chamber measurements. The relationships between R_{CWD} and environmental factors, such as temperature (T) and the water content (θ) of the coarse woody debris (CWD), were determined from long-term continuous measurements. Measurements of the R_{CWD} of many CWD samples revealed relationships between R_{CWD} and CWD characteristics, such as wood density (ρ) and diameter (D). A field survey conducted in 2003 estimated the mass of CWD as 9.30tC·ha^{-1}, with snags amounting to 60% of the total CWD mass. Scaling R_{CWD} to the ecosystem while considering environmental factors according to the type (snag or log) of CWD and CWD characteristics, we estimated that the annual R_{CWD} in the forest was 0.50tC·ha^{-1}·y^{-1} in 2003. This came to 13-19% of the total heterotrophic respiration in the forest. The mean annual CWD input mass from 2000 to 2004 was 0.61tC·ha^{-1}·y^{-1}. Therefore, 0.11tC·ha^{-1}·y^{-1} were sequestered by CWD, which amounted to 7% of the net ecosystem production (NEP) in the forest. In a younger forest, it is difficult to assume that the CWD input and decomposition are balanced, so the R_{CWD} and CWD input mass should be quantified to evaluate the forest carbon cycle and NEP.

INTRODUCTION

CO_2 sequestration in forest ecosystems plays a key role in the global carbon cycle. Forest absorb CO_2 via photosynthesis and release CO_2 via autotrophic and heterotrophic respiration. The net ecosystem production (NEP) is the small difference between the two large fluxes [*Valentini et al*., 2000], so it is necessary to understand the biological and physical controls for all of the processes in a forest to estimate how the carbon cycle in that forest will respond to environmental change. Autotrophic respiration can be considered to quantify net primary production (NPP), while heterotrophic respiration (R_h) has to be treated as an independent compartment, because R_h relies on the amount of dead plant tissues. Coarse woody debris (CWD), because it decomposes slowly, releases CO_2 that affects the carbon cycle of a forest for 10 to 100 years after death. However, the CWD on the forest floor is not included in measurements of soil respiration, and few studies have treated CWD as a CO_2 source [*Chambers et al*. 2004]. Therefore, this study focused on CWD and estimated the annual CO_2 flux from CWD (R_{CWD}) in a forest to evaluate the contribution to heterotrophic respiration and NEP.

SITE DESCRIPTION AND METHODS

R_{CWD} was measured in the Yamashiro Experimental Forest (YEF), in Kyoto, Japan. The forest is situated at a headwater and the plot has an area of 1.7ha. The forest is a secondary deciduous broad-leaved forest dominated by *Qercus serrata* and *Irex pedunculosaa*. The stand density is 3,209 ha^{-1}, the mean crown height is about 12m, and the living biomass (DBH≥3cm) is 44.54tC·ha^{-1} [*Goto et al*., 2003]. The soil is generally thin, immature, and sandy. The CO_2 exchange between the forest and atmosphere was estimated using the eddy covariance method, and the CO_2 flux from each component process, such as photosynthesis, soil, stem, and root respiration, was measured using chamber methods (Kominami *et al*., 2005). Biometric data were also obtained [*Goto et al*., 2003].

An automated chamber was installed on two CWD samples of *Pinus densiflora* and *Quercus serrata* and measured R_{CWD}, T, and θ 72 times a day for about 2 years. The R_{CWD} was measured using a manually controlled chamber system for 192 CWD samples cut from snags and logs in the forest. Environmental factors (T and θ) and CWD characteristics (D and ρ) were also measured. The relationship between R_{CWD}, environmental factors, and CWD characteristics was modeled. Environmental parameters (T and θ) of snags and logs were measured using time domain reflectometry (TDR). The diameter and length of CWD in the forest were measured, and the tree species, position (above or on the ground), and decay class (5 classes) of CWD were also identified in field surveys. We quantified the CWD input mass using tree census data and distinguished live and dead trees once a year for 5 years. The annual R_{CWD} was scaled to the ecosystem after considering environmental factors associated with the position (snag or log) of CWD and CWD characteristics.

RESULTS

Long-term continuous measurements of the R_{CWD} of two samples showed daily and seasonal patterns with changes in *T*. Precipitation events caused notable changes in the R_{CWD} of both samples. Manual measurements of R_{CWD} of 192 samples showed that R_{CWD} was correlated with *T*, θ, ρ, and *D* of CWD and the following function explained 53% of the variance in R_{CWD}.

$$R_{CWD}\ (\mathrm{mgCO_2 \cdot kg^{-1} \cdot h^{-1}}) = 78.5111\exp^{(0.0494Tc)}\ (\theta_{pore}+0.0591)\ (0.871-\theta_{pore})^{0.5814}\ D^{-0.6822}\ \rho^{-0.7900}$$

(T_c (°C): temperature in the chamber, θ_{pore} ($m^3 \cdot m^{-3}$): volumetric water content based on the pore volume of CWD, *D*: diameter, ρ: wood density)

Measurements of environmental factors (*T* and θ) of snags and logs showed that the θ of snags was 20% of that of logs. A field survey conducted in 2003 estimated the CWD mass as 9.30 $tC \cdot ha^{-1}$ (Fig.1). Seventy percent of the CWD had been created before 1999. Snags constituted 60% of the total CWD mass. The annual R_{CWD} estimated in 2003 in YEF was $0.50tC \cdot ha^{-1} \cdot yr^{-1}$, amounting to 13-19% of heterotrophic respiration. The mean annual CWD input from 2000 to 2004 was $0.61tC \cdot ha^{-1} \cdot y^{-1}$, and 60% of this occurred as snags. Snags fell to the ground during sporadic events, such as typhoons. The forest sequestered $0.11tC \cdot ha^{-1} \cdot y^{-1}$ as CWD, which was 7% of the NEP ($1.56tC \cdot ha^{-1} \cdot y^{-1}$) estimated from tower and biometric measurements.

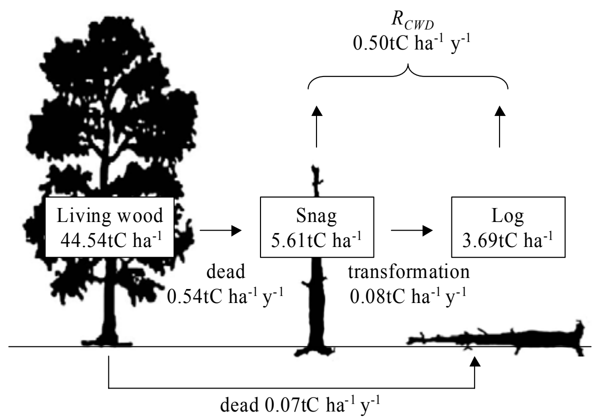

Fig.1 The carbon cycle of coarse woody debris in temperate deciduous broad-leaved forest.

DISCUSSION

R_{CWD} was controlled by both environmental factors and CWD characteristics. In YEF, snags constituted 60% of the total CWD mass. The water content of snags was markedly lower than that of logs. Therefore, the difference in water content due to CWD position (snag or log) affects the annual R_{CWD} in YEF. Most CWD initially occurs as snags, which then fall to the ground during sporadic events and subsequently decompose more rapidly. Therefore, the transformation of snags into logs is an important event in the CWD carbon cycle. Since CWD forms accidentally during disturbances and decomposes more slowly, it is difficult to assume that CWD input and decomposition are balanced. Therefore, in order to quantify the carbon cycle in forest, it may be important to consider the CWD balance in a forest, especially when CWD is abundant in the forest or the forest conditions have recently changed.

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