B-6.2 Quantitative Analysis of a Carbon Cycle in Natural Terrestrial Ecosystems in Cool Temperate Region

Contact Person Akio, TAKENAKA
Global Warming Mechanism Research Team,
Global Environment Division,
National Institute for Environmental Studies
Environment Agency
16-2 Onogawa, Tsukuba, Ibaraki 305 Japan

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Abstract Basic data of the carbon cycling in a broadleaved deciduous forest in cool temperate region of Japan was collected in 1991 and 1992. Amounts of plant litter on and in the soil, soil organic matter, and living plant parts below ground were measured. Moreover, rates of carbon flux were measured for litter fall, decomposition of plant litter, and release of CO_2 from the soil surface. More than 90% of non-living organic carbon was represented by soil organic carbon. Dead logs represented ca. 80% of organic carbon in plant litter. CO_2 flux from the soil surface was shown to closely follow the air temperature. The temperature dependencies of the CO_2 flux varied with season. Large among-site variation was observed even within points only a few meters apart.

Key Words Carbon Cycling, Cool Temperate Region, Forest Ecosystem, Broadleaved Deciduous Forest, CO_2 Flux from Soil

1. Introduction

In order to meet the challenge of global worming problem, the prediction of the future trend in the atmospheric CO_2 concentration is needed. Terrestrial ecosystems with green plants as the main producer of organic substances are recognized to play an important role in the global carbon cycling. Large amount of carbon is absorbed by photosynthesizing plants and released to the atmosphere through the respiration of the plants and other decomposing microbes and consuming animals. They have a potential to affect the future trend of atmospheric CO_2 concentration, and also to be affected by the CO_2 concentration.

One of the characteristic feature of the terrestrial ecosystems is its heterogeneity in time and space in various scales. To estimate the overall function of such heterogeneous systems, we have to classify them, analyze each of the classified sub-systems, and integrate them. The most important factor affecting the structure and function of the terrestrial ecosystems is the climate. Classification of terrestrial ecosystems according to the climate they are exposed to is an appropriate approach and has been widely adopted. The present study project also follows this approach, and this part of the project deals with deciduous forests in the cool temperate region of Japan.

2. Objectives

The objective of the present study is to get quantitative data on the carbon cycling system in a broadleaved deciduous forest in cool temperate Japan. The amount of carbon storage in the forest ecosystem in various forms and the rate of flow of carbon among the pools are to be measured.

3. Methods

The study was conducted in a broadleaved deciduous forest in Nikko district, Tochigi Pref., Japan. The forest stand is at 1500 m a.s.l., in the cool temperate region. Yearly mean temperature is ca. 6°C. A study plot of 1400 m2 was set on a 30-deg south-facing slope. The canopy was dominated by *Quercus mongolica var. grosseserata*, *Acer mono*, and *Ulmus laciniata*. The height of the canopy trees was ca 20 m. The forest floor was exclusively dominated by *Sasa palmata*.

The following items were measured from 1991 to 1992.

(1) Amount and flow rate of dead organic carbon

Amount of organic carbon in plant debris and the rate of its decay was measured. In June of 1991, 10 litter traps of 0.5 m^2 aperture were set within the plot to measure the rate of litter fall from the canopy trees. Ten quadrats of 0.5 m^2 area were set next to the litter traps for collecting litters from *Sasa palmata*. The traps and quadrats were visited once in one or two months and the litters inside them were collected, dried, measured for dry weight, and analyzed for the carbon contents. All the fallen logs were measured for the width and length to estimate the volume.

In October 1991, all the fallen branches 1cm or thicker in width were collected in 300 m^2 area within the study plot. They were dried, weighed, and analyzed for the carbon content. In October 1992, the branches newly dropped within a year were collected in the same area.

In November 1991, fresh dead leaves of trees and *Sasa palmata* and dead culms of *Sasa palmata* were collected and 10 g of them were put into each of bags of nylon net. The bags were left on the forest floor and recovered after a year to measure the reduction of weight due to decomposition within a year.

(2) Soil environment

From July 1991 to November 1992, temperature within the soil was continuously measured at 5, 15, 30 and 60 cm depths. Soil water content was monitored from July to November 1991.

(3) Soil organic substances and underground plant parts

In July 1992, soil samples were collected at 5 points within and near the study plot. Samples were taken for each 5 cm depth from the soil surface to 100 cm. Above- and below-ground parts of *Sasa palmata*, roots of all plants, and A0 (litter) layer on the soil surface were also collected. The whole samples were dried, weighed, and analyzed for carbon content.

(4) CO_2 flux from the soil surface

From August to November 1992, CO_2 flux from the soil surface was measured at four points in the study plot. Air-flow system with infra-red gas analyzer was used to get instantaneous rate of the flux.

4. Results and Discussion

(1) Amount and flow rate of dead organic carbon

Most of the litter fall from the canopy trees was observed in October and early November. There were some variations in the amount of litter fall among the traps, mainly due to the leaves flourishing at the edge of canopy gaps. Not much between-year variation was observed.

Amount of litter from *Sasa palmata* was less than 10% of that from canopy trees (Table 1). There was a large variation among the quadrats in the rate of litter fall from *Sasa palmata* corresponding to the spatial heterogeneity of the plant density.
Carbon contents in the plant litters were 46% and 49% in leaves and twigs of canopy trees, respectively, and 38% and 46% in leaves and culms in *Sasa palmata*, respectively. Rate of carbon flux as the fallen branches represented ca. 5% of that of leaves and twigs.

Many fallen trees were found lying on the forest floor (Fig. 1). The amount of carbon in these logs was estimated from the mean carbon content per unit volume measured for fallen branches, and the volume of the logs based on the width and length of them. The amount was as much as 1.2 kg/m2, which was 5 times as large as that in A0 layer, or the layer of plant debris on the soil surface.

(2) Soil environment

The water content of the forest floor soil scarcely changed during the measurement. It rose more or less during precipitation and returned to the former level soon after the end of the precipitation. The magnitude of the diurnal changes of soil temperatures decreased with the depth, and the phase of the oscillation also shifted with the depth. It is well recognized that the rate of organic matter decomposition within soil is closely related to the temperature. The temperature profile in the soil should be taken into account to analyze the relationships between the CO_2 flux and the soil temperature.

Table 1. Amount of organic carbon and rate of its supply to the soil in various forms measuren in a cool temperate forest of Japan.

Amount of organic carbon	
Fallen trees	1,190 (gC/m2)
Dead branches	48
Sasa (aboveground)	142
Belowground alive plant parts	308
Plant debris in soil	33
Plant debris on soil surface (A0)	177
Soil organic substances	16,700
Rate of supply of organic carbon to the soil	
Litter falls from canopy trees	198 (gC/m2/yr)
Dead branches from canopy trees	11
Dead leaves and culms from *Sasa*	16

(3) Soil organic substances and underground plant parts

Plant parts, plant debris, and soil organic matter distributed mainly near the surface of the soil. Only small portion of them were found beneath 60 – 80 cm depth. The soil organic matter represented about 90 % of belowground organic carbon excluding alive plant parts. Organic carbon present in the A0 layer in July was ca. 83% of that provided as litter fall from the canopy trees and *Sasa palmata*.

(4) CO_2 flux from the soil surface

Fig. 1 shows the temporal changes of CO_2 flux from the soil surface measured at four points from 21 to 23 October, 1992. There was a large variation in the CO_2 flux among the four measuring points. The changing pattern of the flux closely followed that of the air temperature. As the temperature change in the soil goes behind of that of the air temperature (Fig. 2), this close relationships indicate that most of the production of CO_2 in the soil takes place in the shallow layer of the soil. However, the rate of gas diffusion through the soil should also play a role in the rate of CO_2 flux and the mechanism determining the instantaneous rate of CO_2 flux is not straightforward.

Temperature dependency of the CO_2 flux was not constant among the seasons (Fig. 2). From August to November, the CO_2 flux at a given temperature decreased.

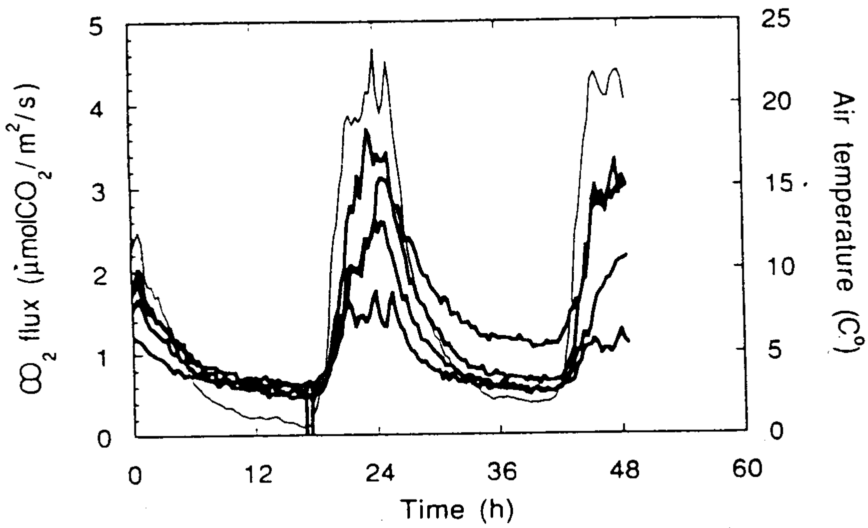

Fig. 1. Temporal changes of CO_2 flux from the soil surface measured from 21 to 23 October, 1992, at four points (thick lines). Air temperature near the soil surface is also shown (thin line).

The possible reasons for this are the decrease in inside–soil temperature even with the same air temperature, and some changes in chemical and physical compositions of plant debris. The changing temperature–dependencies of the soil CO_2 flux should be taken into account in estimating yearly CO_2 release from the soil and the effects of global climate change on the carbon cycle of terrestrial ecosystems.

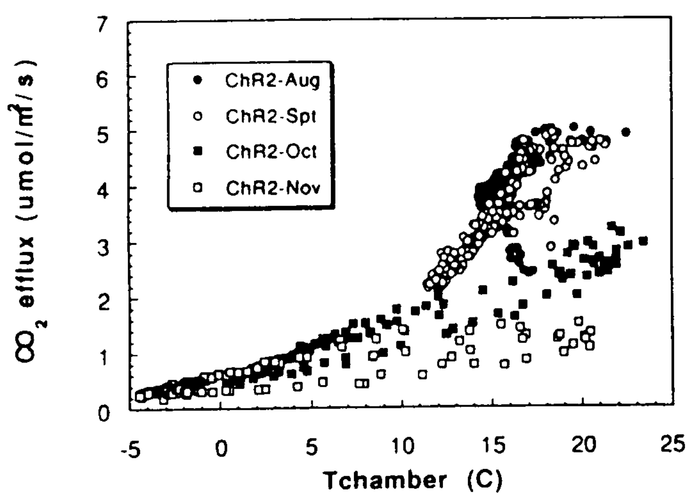

Fig.2. Air temperature–dependency of CzO_2 flux from the soil surface. Different symbols represent data on different month.