B-6.1.3 Modelling and Prediction of Carbon Cycling in a Cool-temperate Forest Ecosystem

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Abstract In order to know carbon cycling in a cool-temperate forest, net ecosystem production(NEP) was examined in a broad-leaved deciduous forest accompanying *Sasa senanensis* as floor vegetation in Takayama experiment forest of Gifu University at 1400m a.s.l. Carbon uptake in *Sasa* floor vegetation became positive in early spring and late autumn only while deciduous trees drop leaves and season free from snow fall. *Sasa* layers expected to fixed 1.18 ton of carbon per year per hectar. 1,868 trees are growing in the forest, which have 186.4 ton/ha of the total dry matter including belowground parts. Radius analysis clarified that 4.05 ton/ha of carbon is fixed by tree layers in a year.

Carbon flux from soil was measured continuously and it was found that soil released 5.61 tonC/ha·yr. Summing up whole carbon budget through the cool-temperate forest eco-system, overall NEP was estimated as 2.19 tonC/ha·yr. These relations were expressed in a compartment model. Both inorganic and organic environmental factors such as light penetration system, or biomass distribution in the experiment forest, were examined to validate the model. Although, prediction model of carbon cycling was not completed because of too short period for forest examination, fundamental data was prepared needed for a dynamic model construction. And several important facts are clarified through the experiments.

Key Words Broad-leaved deciduous forest, Carbon cycle, NEP, *Sasa senanensis*, Soil respiration

1. Introduction

There are still many missing sinks on carbon cycling which make ambiguous carbon budget at grobal scale. It is important to clear these missing sinks within arctic and temperate forest ecosystems, which are thought one of most important zone for carbon fixation. However, very few studies are success to grasp the dynamics quantitatively. There are several reasons for it. First, it takes long time periods and makes strenuous exertions to determine carbon dynamics in forest ecosystems. Second, reliable methodology has not established for measurement of carbon flux from soil layer which should reserve enormous amount of carbon storage. In addition, synthetic data acquisition and unifying analytical methods are very important for forest ecosystem studies, however, it is not established yet. Therefore, it is an urgent subject to develop these methodologies for determining grobal carbon cycling, and build accurate model to predict carbon budget for future.

2. Research Objectives

It is saying that 70% of cool-temperate forests in Japan, their floors are covered by *Sasa* type vegetation and more than 50% of them are dominated by *Sasa senanensis*. However, few studies paid attention to the importance of floor vegetation. So, we have took charge of subject "Quantitative analysis of carbon cycling of *Sasa* vegetation in cool-temperate forest ecosystem" for 3 years from 1993. From this study, we recognized the importance to grasp carbon cycling of entire cool-temperate forest ecosystem and need to predict carbon budget using model.

The purpose of this study is to clarify missing sinks on the terrestrial ecosystems,and establish a full-filled compartment model of carbon cycling in cool-temperate forest ecosystem accompanying *Sasa* as floor vegetation.

Special feature and expected results of this study are as follows;

(1) Cool-temperate forest ecosystem is a diversified ecosystem containing rich floor vegetation, but few studies have cleared and modeled the carbon dynamics of this system.

(2) National Institute of Resources and Environment built an observation tower for measuring carbon flux by aero-dyanamic method at the same site of the forest. We have merits to compare cabon exchange data measured independent methods (Yamamoto et al. 1999).

(3) Among input data of compartment model, variation of environment factors has not attached great importance up to this time. But, the

large variation should exist in environment factors inside forest. We need to consider the variation and validate to reflect on model.

3. Research Methods

Fig.1 shows a schematical carbon cycle in a cool-temperate forest ecosystem with *Sasa* type floor vegetation (Koizumi 1999). Carbon in atmosphere is fixed by trees and floor vegetation as gross production through photosynthsis. After exhausting some parts by respiration, it remains as net production. Others drop as standing dead materials after a period, or grazed by insects, and feed into soil layers. Carbon emission from soil is due to decomposition of organic matter by micro-organisms, respiration by soil animals, and root respiration. We intended to measure carbon dynamics in forest, *Sasa* community and soil quantitatively.

(1) Location, vegetation and climate of experiment site

The experiment site (about 1 ha) was situated at 1,400m a.s.l. on a southwest slope of Mt. Norikura in Takayama, Gifu Prefecture, the central region of Japan. Vegetation of the site is a secondary deciduous forest established after *Fagus crenata* forest was clear-cut about 40 years ago. In present, *Quercus mongolica* var. grosseserata and *Betula ermanii* dominate canopy, and floor vegetation is dominated by *Sasa senanensis*.

The climate of this area belongs to cool-temperate climate, and

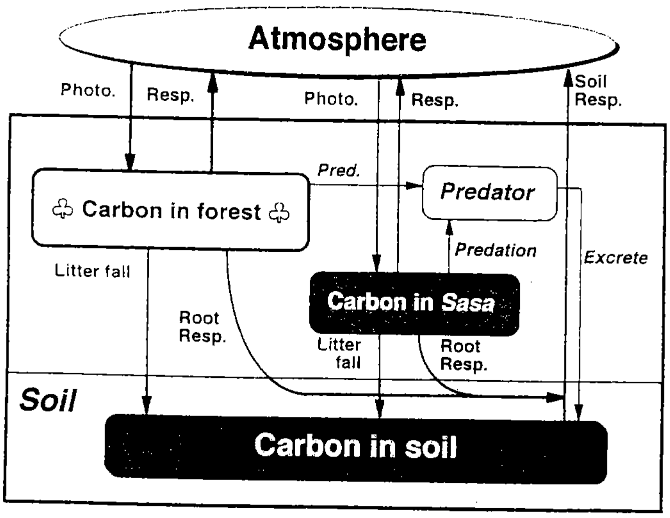

Fig.1 Diagram of Carbon cycle in a cool-temperate forest ecosystem with *Sasa* type floor vegetation (Koizumi 1999)

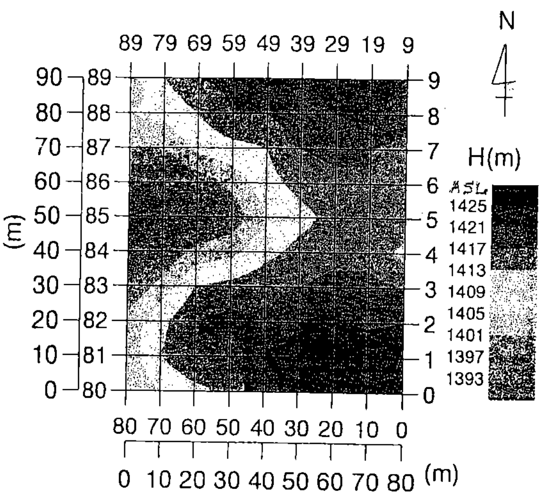

Fig.2 Micro-environment of the test site (Altitude map)

geographic location is at the transitional zone between Pacific type to Japan Sea type climate. Annual mean temperature is 7.2℃, and annual precipitation is 2,344mm according to meteorological record during 1980 to 1997.

(2) Methods

About one third hectar of experiment site, tree species, DBH (Diameter at Breast Height), tree height are measured in March to know forest biomass since 1993. In 1999, this was extended over whole test site. Seven trees were dug underground parts to know top/root ratio, and 15 sample trees of different size were cut for radius analysis to know annual growth. Allometry analysis between DBH and dry weight of each organ was useful to estimate biomass and growth.

Litter bags and litter traps were placed to know the rate of decomposition and amounts of falling leaf and branch.

Seasonal biomass and growth of *Sasa senanensis* were examined every month from April to October for five years. As for aboveground parts, 1m x 2m of samples were cut and separated to know each dry weight, while, 0.5m x 1m with 30cm deep were dug to get underground parts. Respiration rate of plant organs and soil were measured by an infrared gas analyser (Koizumi et al. 1991)

In order to know the variation of micro-environment inside experiment site, the whole site was divided into 10mx10m cells. Micro-topography (Fig.2), seasonal light intensity under forest canopy, and *Sasa* biomass were mesured for each cell.

4. Results and Discussion

(1) Carbon cycle in *Sasa* community

Annual averages of aboveground biomass was estimated as 6.70 ton/ha, while, average of belowground biomass was 5.90 ton/ha. Seasonal biomass changes are shown in Fig.3. Net production (Pn) was calculated following method proposed by Kimura(1976). Seasonal changes of carbon contents and TAC of each organ was examined to know Pn. Pn was estimated 1.18 tonC/ha/yr (Nishimura et al. 1996, 1997, 1999).

Carbon balance sheet of *Sasa* community is shown in Fig.4. It produces positively in spring and autumn seasons, but negative during mid summer. It may be related with seasonal light penetration into floor of deciduous forest.

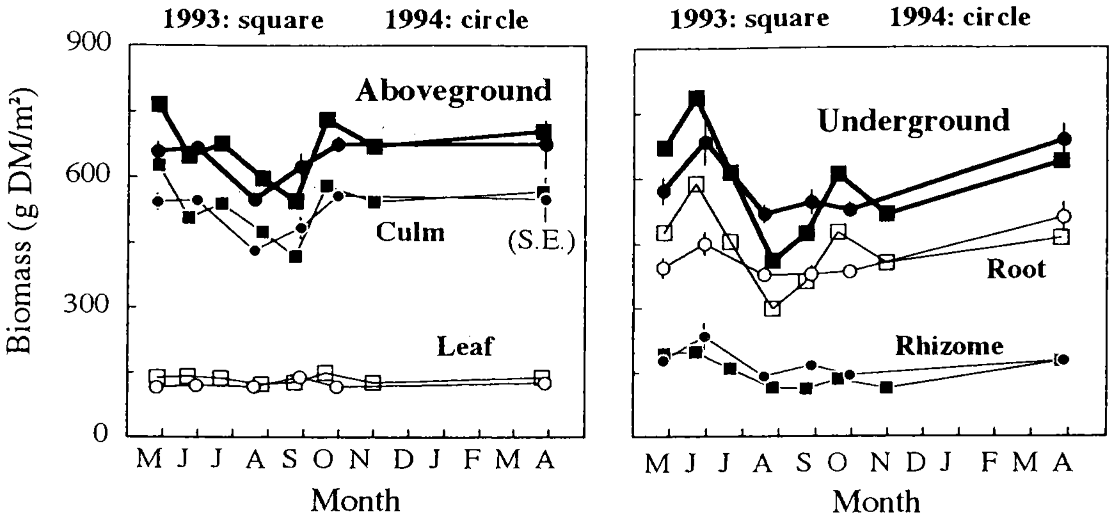

Fig.3 Monthly changes of aboveground (left) and underground (right) dry matter weight in *Sasa* community

(2) Carbon dynamics in forest layer

According to tree census conducted in spring, 1999, it was cleared that tree stem density more than 2cm DBH (Diameter at Breast Height) was 1868 individuals/ha including 33 species, and total basal area was 32.41m²/ha. Among dry weight of plant organs and DBH, it exists allometric relations which shown in Fig.5. Using this relationships, dry weight of trunk, branch, leaf and root were estimated 132.0, 18.7, 3.3 and 32.4 ton/ha, respectively. As results of radius analysis, it was cleared that annual trunk growth was related to DBH (R^2=0.88). Annual growth, loss, and net primary productiion (NPP) of forest layer are summarized in Table 1. It grows 1.16 tonC/ha/yr, and looses 2.90 tonC/ ha/yr. As a total, NPP of this forest was calculated 4.05 tonC/ ha/yr.

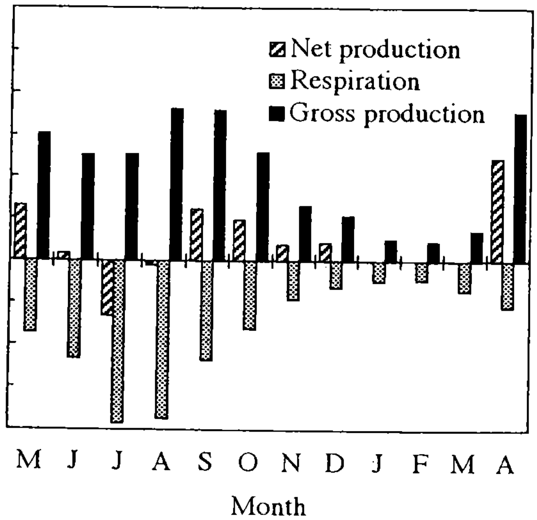

Fig.4 Seasonal changes in monthly net production, respiration and gross production of *Sasa* community

Table 1 Annual growth and loss of biomass and NPP

Annual growth	(ton d.w. ha^{-1} yr^{-1})	(ton C ha^{-1} yr^{-1})
Trunk	2.33	0.93
Branch	0.22	0.09
Root	0.36	0.14
Loss biomass		
Leaf	3.30	1.32
Trunk & root	2.84	1.14
Branch	1.09	0.44
NPP	10.14	4.05

(3) Soil respiraton

Soil respiration was measured monthly intervals from soil surface and snow cover in 1994 and 1995. CO_2 flux was high during summer attaning 600-650mgCO_2/m^2/hr. Even no body measured CO_2 emission from snow surface, it was found that 30-50mg of CO_2 released. Seasonal soil respiratiion is shown in Fig.6.

(4) Net ecosystem production (NEP)

NEP means total carbon balance of entire ecosystem, and described by the following equations.

$$NEP = NPP - (SR - RR)$$
$$SR - RR = HR$$

Table 2 NEP of cool-temperate forest

NPPt (tree)	4.05
NPPs (Sasa)	1.18
SR	5.61
RR	2.57
NEP	2.19

Here, NPP; net production of plant in forest, SR;soil respiraton, RR; root respiration, and HR;soil microbial respiration.

According to this concept, estimation of NEP in cool-temperate forest ecosystem was carried out using measured data from (1) to (3). Even though, RR could not separate from soil respiration, here assumed 45.9% of soil respration averaging several reference data. By this method, NEP finally estimated as 2.19 tonC/ha/yr (Table 2).

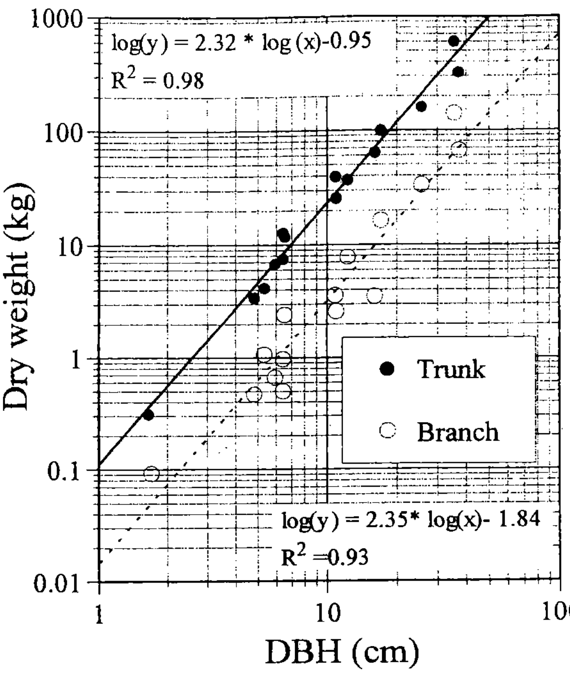

Fig.5 Allometry between DBH and dry weight of trunk and branch

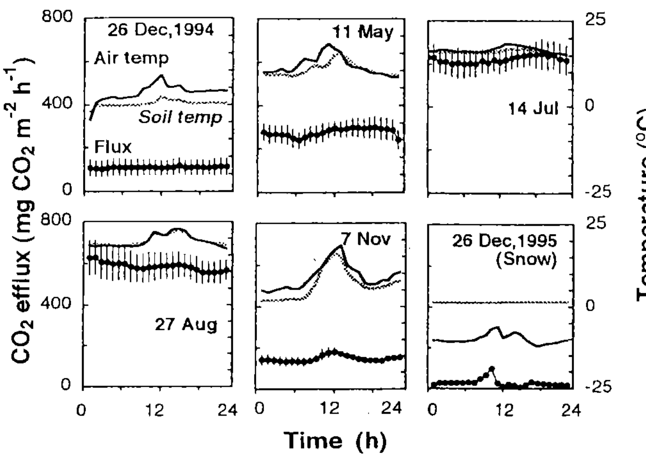

Fig.6 Seasonal changes of soil respiration, air and soil temperature

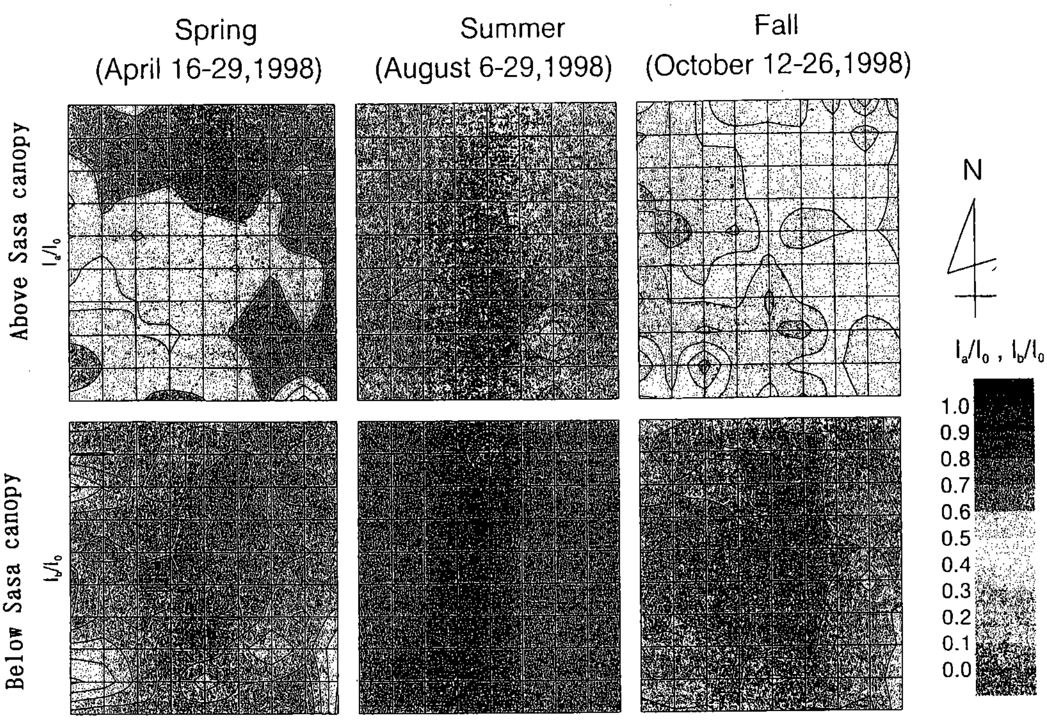

Fig.7 Spacial changes of light penetration at above (top) and below (bottom) *Sasa* canopy

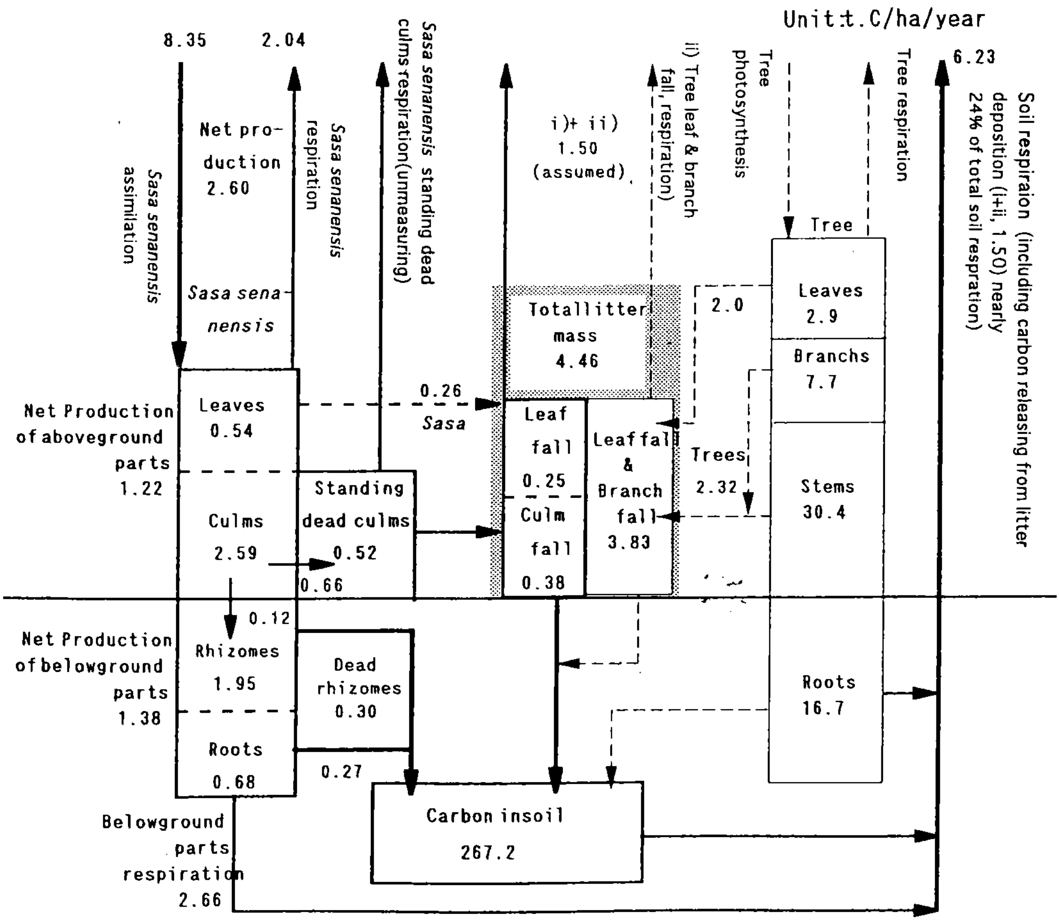

Fig.8 Compartment model of carbon cycle in a deciduous broad-leaved forest with *Sasa* type vegetation in cool-temperate zone (Biomass data were from 1993 to 1997, Takayama experimental field)

This value was a little higher than estmation by eddy correlation method by Yamamoto (1999).

(5) Evaluation of spatial-temporal variation of environmental factors

In order to evaluate spatial-temporal variation of environmental factors, test site was separated ninety 10mx10m cells. In this experiment, variation such as light penetration into forest floor or biomass distribution of *Sasa* community were examined for each cell. Fig.7 shows the spatial and seasonal changes of light intensity measured film solarimeters setting over *Sasa* canopy (150cm) and at the soil surface level(10cm). It gives information about light condition underforest canopy, and dispersion of data in spring and autumn (Akiyama etal, 1998a, 1998b, 1999).

Also, *Sasa* biomass distribution map was created measuring canopy reflectance by portable spectro-radiometer. Here was also found a large spacial difference in biomass.

Fig.8 shows overall compartment model of carbon dynamics in a cool -temperate forest ecosystem in a year. The data in this diagram is tentative one using 1997 data, so need to revise to the latest one, recently.

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