B-6.3 Quantitative Analysis of Carbon Cycling in the Warm-Temperate Forests

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Abstract The soil carbon cycling was observed in a warm-temperate deciduous forest and its clear cutting area in Hiroshima Pref., Japan from 1989 to 1993. The data was analyzed by a compartment and simulation models. The relative de composition rate of A_0 layer was larger in forest (0.42) than in clear cutting stands (0.27 y^{-1}). The value of the former was intermediate between those of beech (0.26) and evergreen oak forests (0.66 y^{-1}). The similar relationship was observed in the relative decomposition rate of humus in mineral soil between three forests. The most flow rates and accumulations decreased drastically just after the cutting. A_0 layer reached to its minimum 10 years, and recovered its most loss within 40～50 years after the cutting. The large minus of carbon balance just after cutting was obseved. The balance, however, change from minus to plus in 10 years after cutting. The loss of carbon from the forest stand following cutting recovered within 20 years, and nearly the same amount of carbon as that stocked in the timbers before the hervesting, accumulated in 70～80 years after the cutting. The calculation by the simulation model was done under the assumption that the increase of atmospheric CO_2 promoted the primary production at 10 % during the last three decades, suggesting that about 9 tC ha^{-1} was sunk into soils of the warm-temperate forest during the same piriod, indicating the posibility of forest soils as the main sink of atmospheric CO_2.

Key Words Carbon budget, Carbon cycling, Missing sink, Simulation, Warm-temperate forest

1. Introduction

In global carbon cycle, the temperate natural ecosystems in the north hemisphere seem to be significant net sinks of CO_2 in constrast to the tropical ecosystems, where the wide deforestation of forests extends rapidly. The sink of natural ecosystems, in particular forest one may contribute to the small net flux from terrestrial ecosystems to the atmosphere in spite of the huge emission of CO_2 due to the burning of fossil fuels.

The objective of this study is to establish quantitatively the warm-temperate forest ecosystems in Japan as sources and sinks on the processes of forest development following a clear cutting, and to evaluate the effects of global warming on the carbon cycling in forest ecosystems.

2. Study area and Metmods

The study site locates in the warm-temperate deciduous broad leaved (Quercus serrata) forest at Yoshiwa in Hiroshima Pref., west Japan. The plots were set up in both matured forest and clear cutting stands in November of 1990. In both stands, the flow rates (litterfall, soil respiration rates) and amounts (A_0 layer, humus in mineral soil, dead roots accumulations) of soil carbon were measured simultaneously with soil environmental condition (temperature and moisture content) through three years (1990-1992), periodically.

The total soil respiration rate in the clear cutting stand were measured from 1991 to 1992 in the frame boxes covered with sheets of white netting, which controlled the soil environmental conditions as same as before clear cutting. The root respiration rates before and after clear cutting were estimated based on the balance of respiration rates between forest stand and frame boxes at clear cutting stand.

The seasonal and annual soil carbon cycling were analyzed by a compartment model (Nakane, 1980)[3] and simulation model(Nakane et al., 1987)[4]. The dynamics of soil carbon cycling and carbon budget with the recovery of vegetation following clear cutting were also analyzed by the simulation model, and estimated the contribution of temperate forest ecosystems as a sink of atomospheric CO_2.

3. Results and Discussion

(1) The soil environmental condition and litter decomposition rate were measured in both forest and clear cutting stands. The daily mean temperature on soil surface was always higher in clear cutting stand than in forest one, but moisture contents of soil, in particular, A_0 layer were lower in the former than the latter.

(2) Annual litterfall rate was 3.5 tC ha^{-1} y^{-1} in the forest stand. Annual averaged accumulation of A_0 layer was 5.8, 2.3 tC ha^{-1} in the forest and clear cutting stands, respectively. The accumulation of humus in mineral soil was estimated at 113.1 and 129.9 tC ha^{-1} in the former and latter, respectively. Total and A_0 layer soil respiration rates were 9.2 and 2.1 tC ha^{-1} y^{-1}

in forest stand, and 6.9 and 0.63 tC ha^{-1} y^{-1} in clear cutting stand, respectively. Annual loss rate of A_0 layer was estimated at 0.58 and 0.43 y^{-1} by litter bag method in the former and latter, respectively.

(3) Based on the observations mentioned above, the soil carbon cycling was analyzed by a compartment model (Nakane 1980). The relative decomposition rate of A_0 layer was larger in forest (0.42) than in clear cutting stands (0.27 y^{-1}). The value of the former was intermediate between those of beech (0.26) and evergreen oak forests (0.66 y^{-1}) (Nakane 1975, 1978)[1),2)]. The similar relationship was observed in the relative decomposition rate of humus in mineral soil between three forests. The reverse relation, however, was observed between forest and clear cutting stands, i.e., the relative rate was lower in the former than the latter due to the higher soil temperature and nealy same moisture content in mineral soil.

(4) Taking into consideration CO_2 evolution due to the decomposition of roots, which were killed by a herbicide after clear cutting, and decrease of A_0 respiration rate, the root respiration rate in forest stand was estimated at 4.0 ～4.7 tC ha^{-1} y^{-1}, based on the balance between those in forest and clear cutting stands. The value corresponded with about 50 % of total soil respiration rate before the cutting. The root respiration rate after the cutting was also estimated at 2.5～3.2 tC ha^{-1} y^{-1}, which was two third of root respiration rate before the cutting.

(5) The seasonal change in soil carbon cycling was calculated by the simulation model. The results of calculation were closely coincided with those obtained in the field. It suggested the reliability of the model. The accumulation of A_0 layer decreased from spring to autumn due to rapid decomposition of litter, and recovered in late of autumn by the largest litterfall. The seasonal change was observed little in the accumulation of humus in mineral soil, owing to smaller input and output of humus than its amount. The total and A_0 layer respiration rates increased from spring to summer and decreased to autumn, corresponding to the change in soil temperature.

(6) The dynamics of soil carbon cycling following clear cutting was simulated by the simulation model, under the condition that soil environmental condition recovered with the regeneration of vegetation, in particular, leaf biomass which was represented by simple logistic curves. The most flow rates, e.g., soil respiration rate and decomposition of litter decreased drastically and reached to its minimum 10 years after the cutting, and recovered its most loss within 40～50 years. The amount of humus in mineral soil, however, increased a little just after the cutting due to the supply of humus from roots killed by cutting, and decreased gradually during three decades and so it took more than 50～60 years after the cutting to recover the most loss.

(7) The change in budget of carbon after clear cutting was estimated by the simulation model, taking the carbon in plant body into consideration. The large minus of carbon balance just after cutting was caused by decomposition of soil organic matters without litterfall (primary production). The balance, however, change from minus to plus 10 years after cutting, owing to the growth of regeneration and its litter supply. The loss of carbon from forest stand following clear cutting recovered within 20 years, and nearly same amount of carbon, which was stocked in the timbers before the hervesting, accumulated in 70~80 years after cutting.

(8) An attempt to solve the missing sink of atmospheric CO_2 was made. The calculation by the simulation model was done under the assumption that the increase of atmospheric CO_2 promoted the primary production at 10 % during the last three decades, i. e., increased 10 % of litterfall and root production rates. The results suggested that about 9 tC ha^{-1} was sunk into soils of the warm-temperate forest during the piriod, indicating the possibility of forest soils as the main sink of atmospheric CO_2.

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