スギ人工林の成長に伴う土壌炭素循環のダイナミクスとシミュレーションによる予測

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Soil carbon dynamics with the stand development of Japanese cedar (Cryptomeria japonica) plantation and the model simulation

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Summary

On the present earth, fossil fuels are being consumed in a large quantity, and so the atmospheric CO_2 concentration has increased rapidly during last several decades. It is important to study the change in the ability of the forest to act as a carbon sink under global warming, as the forest is expected at present to store some parts of increasing amount of CO_2 in atmosphere, which is a major greenhouse gas.

Under such the condition, the meeting in Kyoto (1997) and Haag (2000) were convened, these showed the direction to cut down total CO_2 emission for developed and establish national carbon budgets. Therefore, it is improtant to exactly comprehend absorbing carbon ability in forests and estimate the volume absorbing carbon in future. The simulation of carbon dynamics is most paid attention, and I should need to simulate the forest carbon dynamics exactly in various environment.

In this study, I attemped to analyze the carbon cycling in Japanese cedar (*Cryptomeria japonica* D. Don) plantation at the different developmetal stage by field observation. On the other hand, I attemped to analyze the carbon cycling in cedar plantation by model simulation.

In field observation (Chapter II), this study was carried out in Japanese cedar plantations in Fusedani, Yuki- cho, Hiroshima Prefecture, west Japan. Six study stands, Plots I, II, III, IV, V and VI, were established in plantations with different stages, of which forest ages were 5, 10, 22, 28, 36 and 60- year- old, respectively. The study was carried out simultaneously in all plots (Plots I to VI) from January 1995 to August 1996. I studied the plant biomass, environmental condition (soil temperature and moisture condition), litterfall rate, soil carbon accumulation, soil respiration rate, loss rate of A_0 layer and dead roots and analyzed the soil carbon cycling by a

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compartment model.

The amount of biomass and litterfall rate increased swiftly with the growth of Japanese cedar, which were approximated by a simple logistic function of stand age. The accumulation of A_0 layer decreased from 21 t ha^{-1} to 5 t ha^{-1} during ten years following clear- cutting, and then recovered to nearly the same level as before clear- cutting within twenty years after clear- cutting, although the amount of soil carbon in mineral soil recovered for more than forty years after clear- cutting. Total and mineral soil respiration rates increased rapidly after clear- cutting and gradually decreased in young stands and stabilized in old stands. The relative decomposition rate of the A_0 layer and organic matters in mineral soil was high in the young stands due to the relatively high soil temperature rather than soil moisture content. After the canopy closing up, the relative decomposition rates of the A_0 layer and humus in mineral soil stabilized at 0.14～0.16 y^{-1} and 0.005～0.013 y^{-1}, respectively. Consequently, the soil carbon cycling was strongly affected by clear- cutting, e.g., the amount of soil carbon rapidly decreased due to the cessation of litterfall and increase of relative decomposition rate of A_0 layer and humus, and recovered gradually to the level before clear- cutting with the growth of the cedar plantation. The change in soil carbon cycling with stand development was caused by the change in partly soil temperature and moisture content and most in the amount of cedar litterfall, which changed significantly in the early stage of the stand following clear- cutting, and became slower and leveled off in the late stage with stabilization of the environmental conditions and litterfall rate.

In the analysis by model simulation (Chapter III), the model was calculated by VBA program. In this program, the atmospheric data of 1998 in Hiroshima City. In this simulation, it was take into consideration with the case that forest management (pruning and thinning) was considered, and the case that it was not. Moreover, the results of model simulation were compared to field observation ones (in Chapter II) to check the adaptation of these.

The amount of above-ground biomass and litterfall rate increased swiftly with the growth of Japanese cedar similar to field observation in both simulation (with consideration of forest management and without). Both simulated soil temperatures decreased gradually, and both simulated soil moisture contents in A_0 layer and mineral soil increased by degree with forest age.

Simulated mineral and total soil respiration rate with consideration of the management increased at once from 3.09 and 4.50 to 8.46 and 9.90 t C $ha^{-1}y^{-1}$ just after clear- cutting, respectively, because soil temperature was higher than before clear- cutting and the dead root was occurred by clear- cutting. After that, these decreased gradually and stabilized 2.5 and 4.1 tC $ha^{-1}y^{-1}$ with forest development, respectively. Simulated mineral and total soil respiration rate without consideration of the management showed same change as that considered the management until 20- year- old, and after that, these stabilized 2.6 and 4.9 tC $ha^{-1}y^{-1}$, respectively. Both simulated A_0 layer soil respiration rate with consideration of the management and without decreased swiftly from 1.44 to 0.42 tC $ha^{-1}y^{-1}$ after a little increase because the litterfall rate was stopped by clear- cutting. After that, these increased with forest age and recovers of litterfall and the biomass of leaf and branch, and after that, it stabilized 1.58 and 1.47 tC $ha^{-1}y^{-1}$ in mature forest, respectively.

Simulated carbon accumulation in A_0 layer with consideration of the management and without decreased from 9.8 and 9.8 to 2.4 and 2.8 tC ha^{-1} (10- year- old), respectively, and these recovered later with forest development and the recover of litterfall rate. Simulated carbon accumulation in A_0 layer with consideration of the management and without stabilized about 11 and 10 tC ha^{-1} in mature forest, respectively. In simulated carbon accumulation in mineral soil with consideration of the management and without, both carbon accumulation decreased from 110 to 90 tC ha^{-1} until 20- year- old after clear- cutting because the carbon accumulation in A_0 layer was lower, and after that, these increased gradually with recovering of litterfall rate and turnover rate of fine root. Both carbon accumulation almost stabilized about 120 tC ha^{-1} around 100- year- old. Simulated carbon accumulation in dead root considered the management and not decreased from 24 and 24 to 2.4 and 3.0 tC ha^{-1}, and after that, these increased slightly and stabilized later about 4.7 and 4.1 tC ha^{-1}, respectively.

When the forest management (pruning, first thinning and second thinning) was carried out, model simulation showed the change correlating to the management, e.g., the carbon accumulation of A_0 layer decreased from 9.4 to 8.8 tC ha^{-1} and the respiration rate of A_0 layer decreased once from 1.34 to 1.29 tC ha^{-1} y^{-1} af first thinning. In respiration rate (A_0, mineral and total) and carbon accumulation (A_0 layer, mineral soil and dead root), there were not a significant differences among the observation, simulation considered the management and not ($p<0.05$, by one- way analysis of variance).

As this model simulation could be simulated exactly by using air temperature, precipitation and the amount of snow cover, it was usable for management plan of Japanese cedar plantation which was not understood how it was managed up to now. When the carbon cycling could be simulated truly, I could announce about every cedar plantation specifically in Japan.