B-4. 2.2 Effect of forest fire on a carbon budget (Final Report)

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Total Budget for FY 1994-1996 25,510,000 Yen (FY1996 9,433,000 Yen)

Abstract

We evaluated the forest fire occurs in Siberian larch forests established on permafrost area from various view points.

(1)We observed an increment of active-layer thickness, or distance from soil surface to permafrost, after one year of forest fire in a larch forest in central Siberia. Soil CO_2 emission decreased after one year of forest fire because of damage of roots of vegetation by a forest fire. Soil CO_2 emission closely related with a cover degree of lichens.

(2) We analyzed water which was running off two kinds of the forests before and after fire. Any ammonium and nitrate nitrogen were not observed in the water.

(3) We made a new chamber of 5 m^3 for non-destructive measurement of day-time respiration of above-ground parts of a whole plant.

(4) We found close relationships between respiration rates of root and stem, and the diameters of the parts. On the basis of the relationship, we estimated respiration rate of under-ground parts of whole plant without destruction using mathematical model.

(5) Ratio of respiratory consumption to gross production in a Siberian larch forest without fire was estimated to be 0.26. The value is the smallest one in various forests all over the world.

(6) We established the method to reconstruct the past structures, or density, stem volume, and stem volume growth and function, or respiratory consumption in a forest. Using the method, we estimated the past structure and function in a Siberian larch forest after a forest fire.

Key Words: Global warming, Forest fire, Permafrost, Carbon budget

Introduction

Siberian larch forests have the biggest phytomass and area in various terrestrial ecosystems on northern hemisphere, and are established on permafrost specific to the forest area. Therefore, the forests are predicted to be easily affected by forest fires which have been burning the huge area of the Siberian larch forests. In the present project, we evaluate the forest fire on the basis of estimation of carbon cycle comparing forests before and after forest fire.

Materials and methods

We used the long-term monitoring plot managed by the Skachev Institute of Forest located in central Siberia on continuous permafrost area. We measured the thickness of active-layer, and soil CO_2 emission in burned and unburned sites. In the unburned site, we compared the relationship between soil CO_2 emission rates and cover degrees among various vegitations.

We estimated a carbon-budget in a forest which recovered from a big forest fire occurred in 200 years ago, on the basis of non-destructive measurement of whole plant respiration including under-ground parts, and on analysis of annual rings of stems, roots, branches and litterfall rate. Then, we reconstructed the past structure and function of the forest by mathematical model using the estimated carbon-budget.

Results

We observed an obvious increment in thickness of active-layer after forest fire as shown in Fig. 1. The thickness in burned and unburned sites were respectively 30-50 and 40-80 cm.

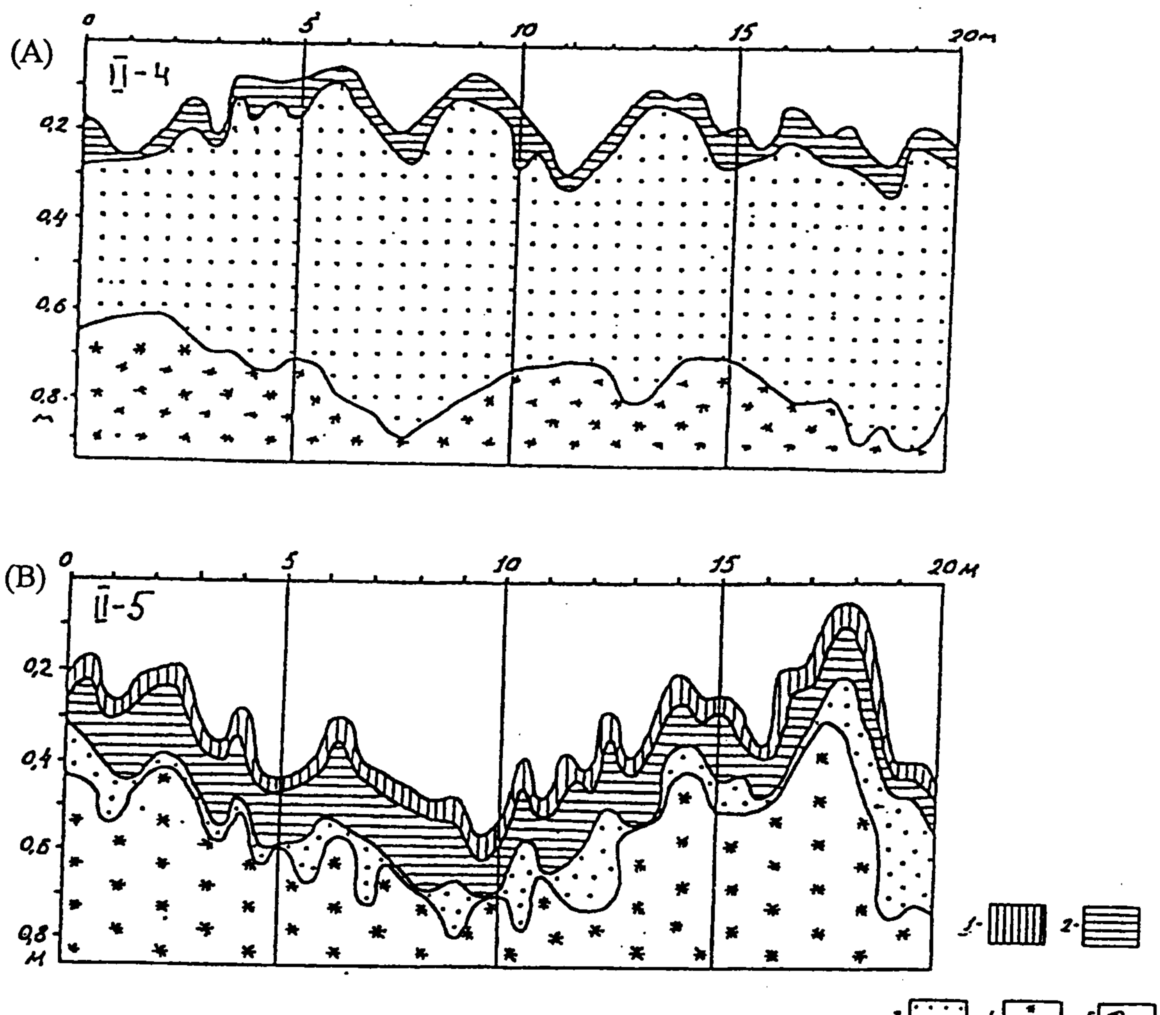

Fig. 1. Soil profile of burned (A) and unburned (B) sites.
1:litter, 2: organic matter, 3:melted mineral soil, 4:frozen soil, 5:large root.

Irrespective of the increment of the thickness, soil CO_2 emission in unburned site is larger than that in burned site (Fig. 2) because of a damage of roots by forest fire. We found the most close relationship between soil CO_2 emission in burned site and cover degree of lichen among various vegetation species as shown in Fig. 3.

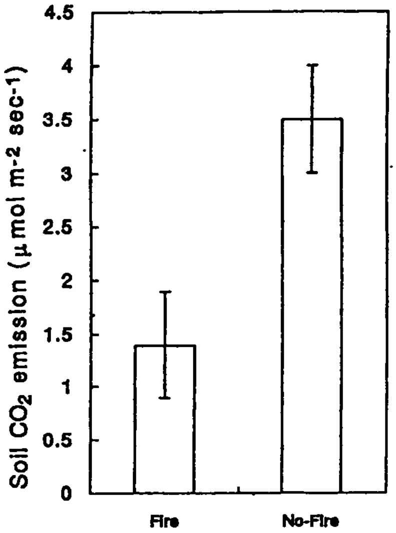

Fig. 2. Comparison of soil CO_2 emission in burned and un-burned sites.

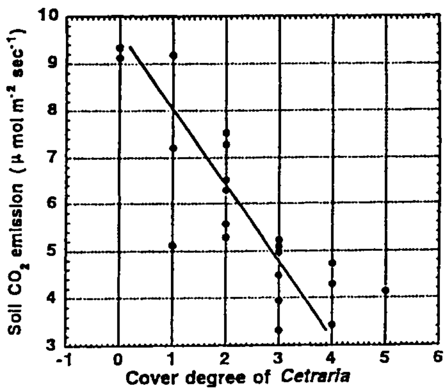

Fig. 3. Relationship between soil CO_2 emission and cover degree of lichen (Cetraria).

We measured the whole plant respiration of above-ground parts using dark-chamber of about 5 m^3 using close-gas-cycle system (Fig. 4). On the basis of seasonal change of air temperature as depicted in Fig. 5, we estimated seasonal change of respiration rate of above-ground parts in the forest as shown in Fig. 6.

We found the close relationship between respiration rate of roots and diameter as shown in Fig. 7, and estimated the seasonal change of roots respiration rate (Fig. 6) by seasonal change of soil temperature (Fig. 5) using mathematical model proposed by Mori and Hagihara (1991).

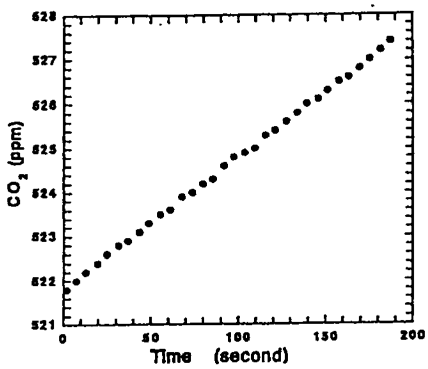

Fig. 4. An example of increment of CO_2 concentration in closed-gas-cycle system.

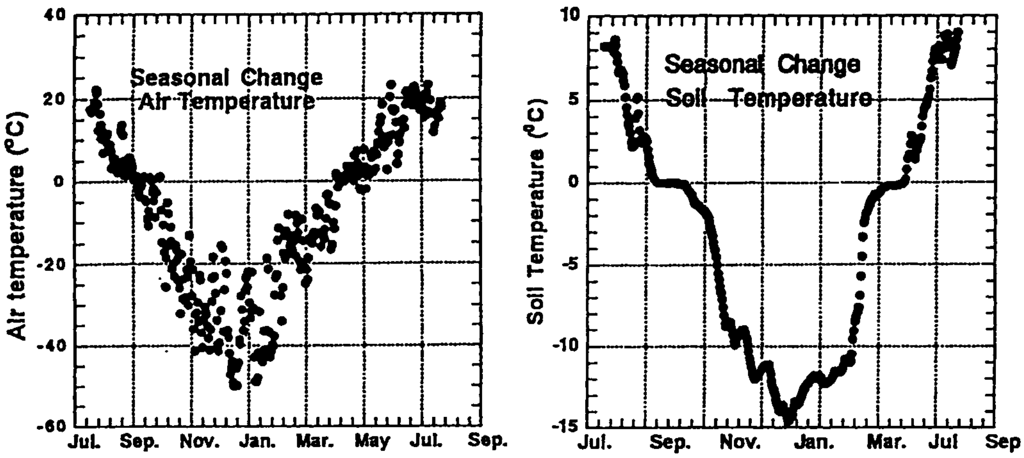

Fig. 5. Seasonal change of air and soil temperature at 20 cm under ground surface.

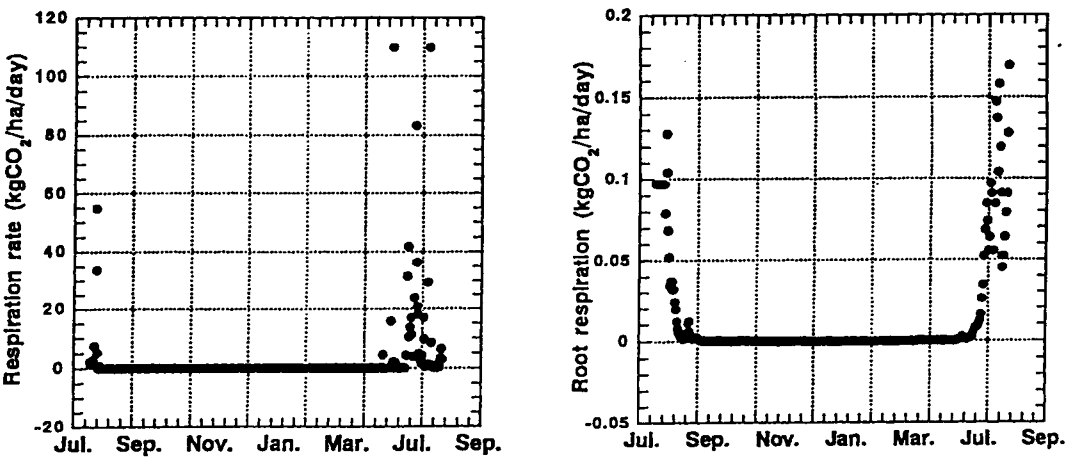

Fig. 6. Seasonal change of respiration rate of above- and under- ground parts in the forest.

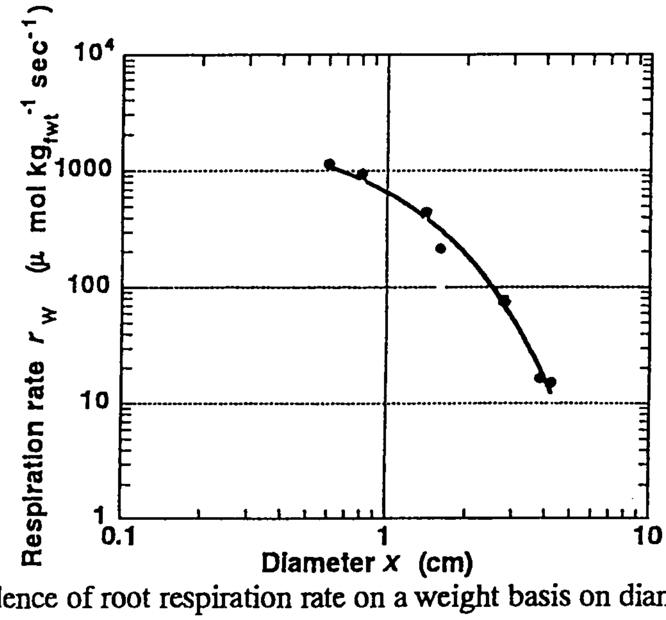

Fig. 7. Dependence of root respiration rate on a weight basis on diameter.

On the basis of the seasonal changes of respiration rates of above- and under-ground parts, we estimated the carbon-budget in the study site as depicted in Table 1.

Table 1. CO_2 budget in the study site. (ton/ha/Yr)

	Biomass	Net Prod.	Resp.	Resp./Biomass
Stem	29.5	0.31		
Branch	5.87	0.0815	0.806	0.022
Leaf	1.63	1.63		
Root	19.7	0.23	0.0054	0.00027
Soil CO_2 Emission			0.0071	

Next we made a mathematical model to reconstruct the past structure and function of the study site after forest fire. By the model, we estimated the recovery process of forest from damage of forest fire as shown in Fig. 8. The estimated value of respiratory consumption Ra in the present forest was similar to the actual measured value using above mentioned procedure.

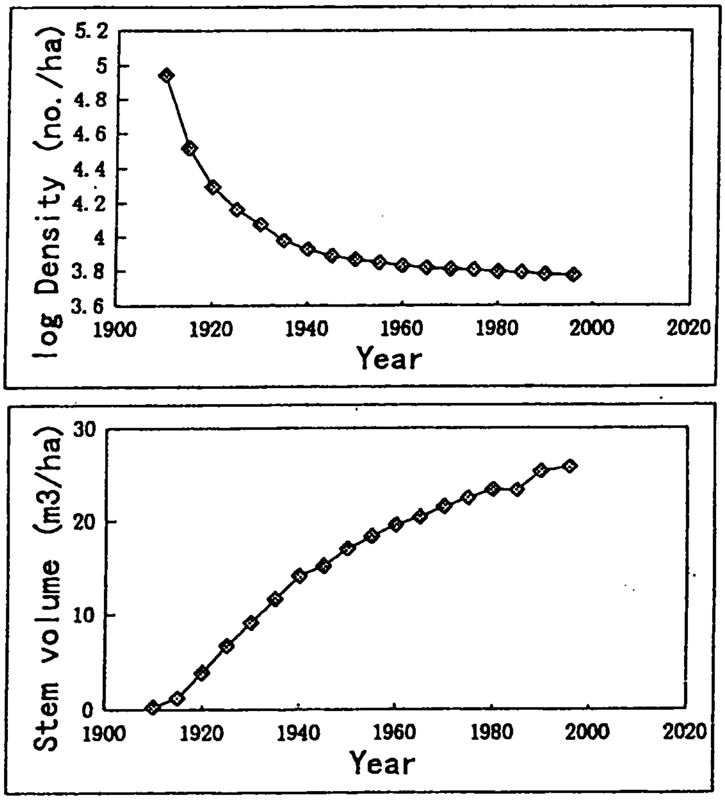

Fig. 8-1. Estimated past density, stem volume, stem growth, and respiration rate Ra of above ground parts.

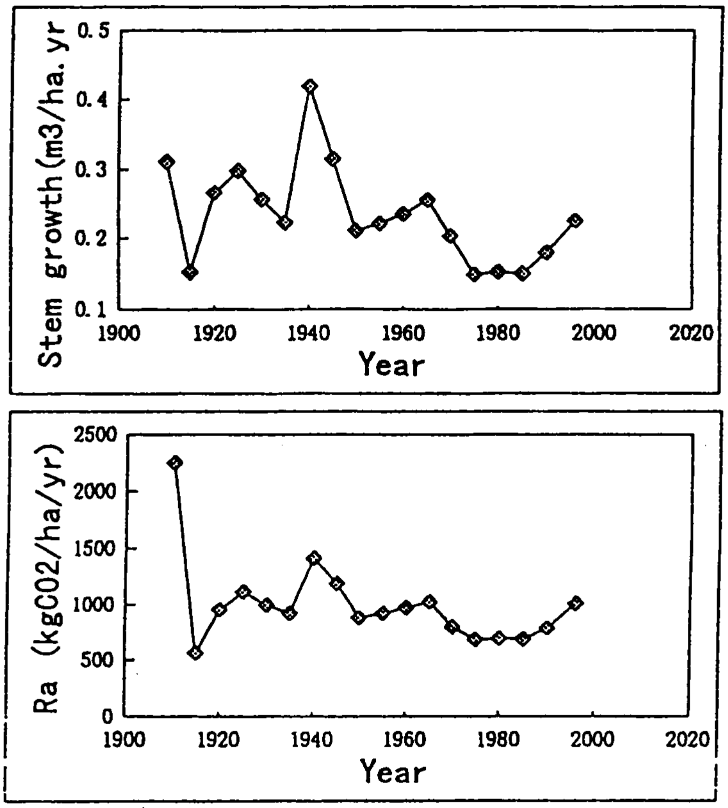

Fig. 8-2. Estimated past density, stem volume, stem growth, and respiration rate Ra of above ground parts (continued).

Discussion

Thickness of active layer increased, after one year of forest fire. The increment of the active-layer occurred usually promotion of decomposition of organic matter. However, we observed an obvious decrease in soil CO_2 emission after one year of forest fire. On the other hand, large part of soil CO_2 emission was occupied by roots CO_2 emission as shown in Table 1. Furthermore, in the study site the forest fire damaged severely the vegitaion. Therefore, the decrease in soil CO_2 emission was probably caused by the damage of roots by forest fire.

The soil CO_2 emission closely related with cover degree of lichen in the unburned site. The emission rate was in inverse proportion to the degree as shown in Fig. 3. On the other hand, lichens are widely known to produce chemicals damaging plant growth, or root growth which is the most important factor to CO_2 emission in Siberian larch forests. High-cover degree of lichen disturbed the root growth. Therefore, the close relationship was likely caused by the disturbance of plant root growth. Furthermore, in Siberia, we observed low tree density in the area with high-cover degree of lichen which was able to be seen as white cover from helicopter flight. In the area, we could not see youg vigorous trees, and could see old weak trees. We concluded that the forest structure, function and regeneration were probably effected by lichens in Siberia.

We estimated the past structure and function of forest which had been recovering from damage of forest fire as shown in Fig. 8 on the basis of actual values. The estimated values in Fig. 8 were calculated by the actual measurements of whole plant respiration including under ground parts (Fig. 6) using non-destructive methods (Figs. 4, 7) . This was the first study to estimate total carbon-budget on the basis of non-destrctutive method including under ground parts in a matured forest whose age was over 200 years.