B-4.2.1 Primary production and CO_2 budget in forest ecosystems (Final Report)

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Abstract

We conducted above- and below-ground biomass study, stem and root growth analyses, soil organic carbon and nitrogen storage estimation, and growth experiments under high temperature and doubling CO_2. We summarize ecosystem characteristics in continuous permafrost larch ecosystems as follows;

(1) About 30 to 40 % of total biomass accumulated in the below-ground part in forest tundra ecosystems in eastern Siberia and taiga in central Siberia.

(2) Root growth rate might be affected by the environmental factors which were made by micro-topography. The functional relationship between stand level volume growth and carbon dynamics in the past was suggested.

(3) Organic soils and podzolic soils were not prevailing in eastern Siberia. Most soils of forest tundra had relatively low C/N ratio (below 15). On the other hand, soils in central Siberia and mountain forest tundra in eastern Siberia had higher C/N ratio (about 20), which was general cases in other circumpolar ecosystems.

(4) Further researches on biomass allocation, functional reconstruction in a stand level, and ecosystem process in potentially nitrogen rich condition under global warming are needed.

Key Words Above- and below-ground biomass, Soil organic carbon, C/N ratio, Continuous permafrost, Larch ecosystems

1. Introduction

Ecosystems in eastern Siberia are dominated by larch forests which developed on the continuous permafrost. Such characteristics does not exist in other circumpolar region. Many previous studies on northern forest and forest tundra have dealt with structure and function of ecosystems in permafrost free or discontinuous permafrost region of North America. It is still important to estimate plant biomass and soil characteristics in continuous permafrost ecosystems, in order to understand the effects of global warming on the terrestrial ecosystems of north-eastern Eurasian Continent.

2. Study sites and Methods

We selected two forest tundra sites and one mountain forest tundra site in eastern Siberia, one taiga forest in central Siberia. Forest tundra sites were located on the lower Lena River region (72N-126E), and Kolyma lowland (69N-160E). Research site of mountain forest tundra was located on the upper Indigirka River (63N-145E). The taiga research site in central Siberia was located on one of the tributary of Nidjunya-Tunguska River (64N-100E). These research sites were on the continuous permafrost.

Above- and below-ground biomass were estimated using the allometric relationships obtained in each research site. We also analyzed stem and lateral root growth by tree ring analysis. Soil organic carbon and total nitrogen were determined within 1m depth of fourteen pedons in research sites. Growth experiments of *Betula platyphylla* under high temperature and doubling CO_2 concentration.

3. Results

Biomass and growth analysis

Total biomass of forest tundra ecosystem in Kolyma lowland was 26.6 ton/ha, of which 39.8 % was below-ground biomass. In mountain forest tundra of upper Indigirka, total biomass was only 9.9 ton/ha, however, relatively high proportion (27.6 %) of total biomass accumulated in below-ground part, same as in Kolyma lowland. Taiga in central Siberia research site had the largest total biomass (34.4 ton/ha) among these sites, with the same biomass allocation rate to below-ground part (about 35 %).

Table-1. Biomass accumulation and allocation of larch ecosystems in eastern and central Siberia.

site	Eastern Siberia		Central Siberia
	Cherskiy (Kolyma lowland)	Oymyakon (upper Indigirka)	Tura (Nidjunya-Tunguska)
Biomass (t/ha)			
Stem	11.9 (44.7)	6.1 (61.5)	18.1 (52.6)
Branch	3.2 (12.0)	0.9 (9.0)	3.2 (9.3)
Needle	0.9 (3.5)	0.2 (1.9)	1.0 (2.9)
Above-ground	16.0 (60.2)	7.2 (72.6)	22.3 (64.8)
Roots	10.6 (39.8)	2.7 (27.6)	12.1 (35.2)
Total	26.6 (100%)	9.9 (100%)	34.4 (100%)

Growth rate of lateral roots was estimated. The average growth rate was ranging from 0.3 to 11.5 cm/yr, with no apparent synchronized root elongation pattern within the same individuals.

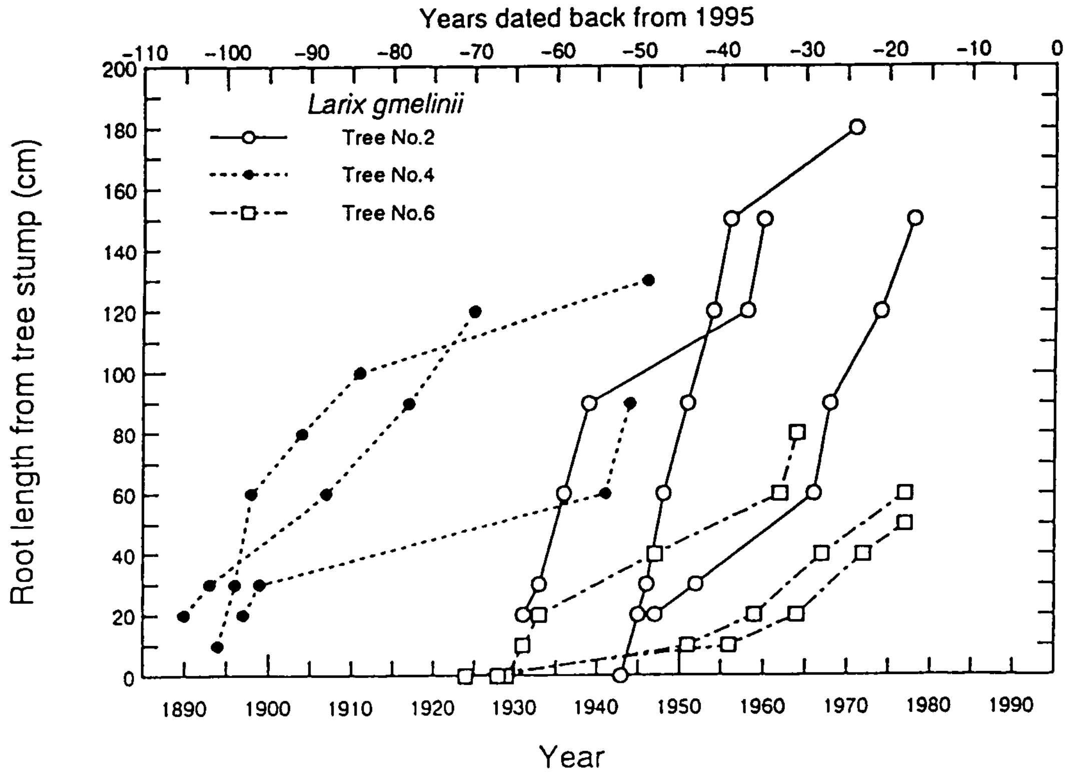

Fig-1. Root elongation pattern of larch trees in Tura, central Siberia.

Soil organic carbon and nitrogen storage

Organic soils were not prevailing in dry and mesic forest tundra. Most soils were classified as Pergelic Cryorthents and Pergelic Cryochrepts. Organic soil distribution was restricted in the wet site, such as surrounds of thermokarst lakes. Soil organic carbon and total nitrogen storage were shown in Table-2. The SOC and TN storage of these soils had a wide variation among soils ranging from 12.8 to 64.6 kgC/m^3, and from 0.62 to 3.02 kgN/m^3, respectively. More SOC and TN accumulated in wet forest tundra and bog tundra soils than in dry and mesic forest tundra soils. The least SOC and TN storage occurred in the taiga soils of central Siberia. Since soils of dry and mesic forest tundra had relatively large amount of total nitrogen, C/N ratio were about 13. On the other hand, soils of wet environment, such as wet forest tundra and bog, showed high C/N ratio (above 20). Mountain forest tundra soil also showed high C/N ratio (C/N=18.8).

Table-2. Soil organic carbon (SOC), total nitrogen (TN), and C/N ratio of soils in forest tundra and mountain forest tundra in eastern Siberia, and of a taiga soil in central Siberia.

Research site	Site condition	SOC	TN	C/N	n
		----- kg/m^3 -----			
Forest tundra soils					
Lower Lena	mesic to wet (terrace)	64.6	3.02	21.4	3
	dry (slope)	21.6	1.60	13.5	4
Kolyma lowland	mesic (terrace)	15.3	1.22	12.6	2
	wet bog tundra	59.5	2.15	27.6	2
Mountain forest tundra					
Upper Indigirka	dry (upper slope)	21.6	1.15	18.8	1
Taiga in central Siberia					
Tura	dry to mesic (terrace and slope)	12.8	0.62	20.6	2

Growth experiment

Effects of high CO_2 concentration on carboxylation efficiency under both low and high temperature treatments were more evident in Japanese population of *Betula platyphylla* than in population in Yakutsk. Japanese white birch showed remarkable decline of carboxylation efficiency. Net photosynthetic rate per unit leaf nitrogen increased in both Japanese and Yakutian white birch seedlings.

4. Discussion

The proportion of below-ground part in continuous permafrost larch ecosystems were much higher than those of previous studies in other forests. About 30 or 40 % of total biomass was root biomass. Such characteristics might be one of the plant traits for severe environmental conditions. Because *Larix* is deciduous species, needle does not play any role for the reservoir during the dormant period. Thus, root system of larch may have some function of reservoir organ.

There are several environmental factors which have effects on root growth pattern in the active layers. Because there is typical soil surface morphological features in continuous permafrost region, the differences in soil temperature, moisture condition, and nutritional status (such as nitrogen mineralization rate) which were formed by micro-topographical position may affect the root growth.

Although northern forest tundra soils had wide variance in soil organic carbon and total nitrogen storage, most of these soils showed the lower value of C/N ratio ranging from 9 to 15. Organic soils with thick raw humus accumulation occurred where wet forest tundra and bog around thermokarst lakes were dominant landscapes. Most soils in eastern Siberia might be derived from the parent materials which was old sediment of huge rivers and galciation-free sediment with relatively high humus content. On the other hand, parent materials of soils in central Siberia and mountain forest tundra soils in eastern Siberia was weathered rock fragments which had been glaciated or been located on the periglacial regions in the past.

Soil organic carbon and total nitrogen storage pattern was quite different from that of other ecosystems in circumpolar region.

Biomass allocation pattern, soil organic carbon and nitrogen storage, and ecophysiological traits of trees may affect the carbon dynamics and budget of such northern terrestrial ecosystems of larch in continuous permafrost region. Climate change may also affect the ecosystem function and structure in the course of the different scenario from in the north America where no forest ecosystem exists on the continuous permafrost.