B-4.3 Carbon Storage and Carbon Dioxide Budget in Forest Ecosystems

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Abstruct The purpose of our research project is to clarify the following four main areas for representative forests in the permafrost regions of Siberia in relation to the effect of global warming; 1)Estimation of forest biomas and carbon storage in forests and forest soils; 2) Dendroclimatological analysis of tree growth; 3)Estimation of yearly uptake of CO_2 by forests and CO_2 flux in forests; 4)Gas exchange capacity in representative tree species in relation to adaptation to environmental fluctuation. The field investigation in Yakutia was carried out in summer of 1992 and 1993. Total biomass of a *Larix gmelinii* stand was 271.5 ton/ha/yr. Primary net production was estimated at 3.1 ton/ha/yr. Leaf dry mass of 1.7 ton/ha/yr was about a half in Japanese larch forest. Carbon and Nitrogen storage of the forest soils were estimated on the both sides of the Lena River. Soils developed on the both sides had a big difference in organic- and inorganic-carbon storage. Tree ring analysis indicated a peculiar ca. 30-year cycle of growth shift events in larch. Characteristics of gas exchange capacity in major tree species and adaptability to elevated CO_2 in birch were examined. Clear midday depression in photosynthesis occured in both larch and pine because of the low xylem water potential. Topographic characteristics in distribution of major tree species were clarrified by using a LANDSAT image. These field studies were carried out by support of Yakutsk Institute of Biology, Russian Academy of Science.

Key Words Siberian Forests, Permafrost, Carbon Budget, Forest Biomass, Dendroclimatology

1. Introduction

Increase in the concentration of atmospheric carbon dioxide has been over one ppm/year in recent years. Such increase in carbon dioxide may result in the rise of air temperature at a magnitude of two degrees C in 50 years. Rapid temperature rise would greatly affect the forest ecosystems. The effect is particularly keen in boreal forest ecosystems where approximately 25% of total edaphic carbon of the earth's surface is stored. Little is known about the carbon balance of Taiga that occupies much of the Siberian permafrost regions. To know whether the huge Siberian Taiga is a sink or a source of carbon dioxide is very important for us to estimate the influences of global warming on the Taiga. Our research project is to be focused on these problems.

2. Objectives

The objectives of our research project are to clarify the following four main areas for representative forests in the permafrost regions of Siberia in relation to the effect of global warming.

1) Estimation of forest biomas and carbon storage in forests and forest soils
2) Dendroclimatological analysis to analyze patterns of tree growth and to recostruct history of non–catastrophic forest fires
3) Estimation of yearly uptake of CO_2 by forests and CO_2 flux in forests
4) Photosynthetic, respiratory, and evaporative characteristics in representative tree species in relation to adaptation to environmental fluctuation

3. Materials and Methods

The studies were carried out at Spaskayapad Experiment Forest(62°15'E, 129°36'E) located at ca. 30km north of Yakutsk city and on the terrace of the left side of the Lena River and at Model Alas Experimental Field(62°09'N, 130°38'E) on the right side of the Lena River.

In Spaskayapad, we selected one plot of which size was ca. 50m x 50m. Five larch trees covering various size were selected as sample trees and cut down at the groud level after the DBH and tree hight of all trees in the plot. Roots of sample trees were dug out after cutting the tree at stump height and weighed as in stem and branches. From subsamples of branches, leaves, and current shoots, samll and big branches were separated and their green weight was recorded. The same work as in larch trees were applied to all shrubs growin in an area of 1m x 50m. Primary productivity was estimated by recent growth of annual rings of stems and branches. Annual growth of underground part was estimated by using top/root ratio.

Stem incremant cores were collected from breast height of 104 larch trees in two bog areas in Spaskayapad. Two cores were taken from each samples tree at opposit sides of the stem. The stem diameter at breast height(dbh) was also measured. The widths of the growth rings and bark thickness were measures with a tree–ring analyzer to 0.01 mm accuracy. The data were then corrected to reflect the stem sizes of the sample trees under the field condition; the dbh, bark thickness and the length of the air–dried core were used for the correction. The tree ring data were then converted to those of stem cross sectional area for the analysis with the U–W phase diagrams[1)].

Soil survey was carried out at Spaskayapad and Model Alas. Six profiles were descibed along a toposequence, where vegetation continuum, pine(dry) – larch(mesic) – carex tocksock, was established at Spaskayapad and morphological features of six profiles were examined at Model Alas. Carbonate carbon content was analyzed with volumetric calcimeter. Subsamples were ground and oven–dried for the determinations of total N and C contents by dry–combustion method. Organic–C content was estimated by subtracting carbonate–C from total–C. Storage in active layers were estimated by using values of bulk density, horizon thickness, and content of each element.

Photosynthesis and transpiration were determined by portable infra–red gas analyzer(KIP–9010) with using an acryl assimilation chamber. Intact current year leaves of larch, pine and birch were examined with 10 minutes intervals. The pressure chamber method was applied in order to determine the tree water condition as xylem potential. The effects of increased carbon dioxide and temperature on the growth and photosynthetic capacity of white birch native to Siberian and Japanese were examined.

Topographic characteristics in distribution of major tree species around Spaskayapad Experimental Forest were clarrified by using a LANDSAT image.

4. Result and Discussion

Estimation of biomass: Main statistics of this stand were as follows; 900 trees/ha for stand density, 17m for mean tree height, 18cm for mean DBH, and 153 cubic m/ha for growing stock. The results of biomass estimation are given in Table 1. There still remains some doutful figures as indicated by question marks. As compared with Japanese larch(*L. kaempferi*) forests, a distinctive feature of the estimates is the leaf mass of 1.68 ton/ha, which is approximately equivalent to half of Japanese larch[2]. Fig.1 shows vertical distribution of the biomass. As shown in the right figure, organic matter concentrated in the layer between 0.3 and −0.7m from the ground level. The primary net production was estimated 3.1 ton/ha/yr, which is much smaller than the value of 14.6 ton/ha/yr obtained in a Japanes larch[2]. The uptake of carbon dioxide by this stand is estimated 5.4 ton/ha/yr from the value of 3.1 ton/ha/yr for the primary net production.

Dendroclimatological analysis: Approx. 30−year cycle of growth shifts was observed in the tree ring data. This cycle appears to be unchanged during the entire period of observation since early 1700's. The value of *W* index also did not change very much during the past 100 years since the end of Little Ice Age and this is associated with the absence of clear correlation between the *W* index and the atomospheric carbon dioxide levels. Forest fires were identified to have occurred in 1859, 1889, 1922 and 1936. The pattern of ca.30−year cycle seems to have changed, however, after 1930s. Patterns of standardized growth index for stem cross−sectional area area growth and percentages of growth shifts both indicated similar ca.30−year cycles.

Soil survey: Fig.2 and 3 shows schematic representation of soil catena an vegetation types in Spaskayapad and Model Alas respectivly. The active layer depth in *Pinus* stand deeper than any other forests and the deepest active layer was found at the lower part of a slope facing the south in Alas. The estimated stocks of carbon and nitrogen were shown in Table 2 and 3. Soils developed on the both sides of the Lena River has a big difference in chemical properties, especially in organic− and inorganic−carbon storage.

Gas exchange capacity of main tree species: Typical midday depression of the photosynthe−sis and transpiration were observed in larch and pine because of low xylem water potential and high leaf temperature, but did not observed in white birch. Two coniferous species are growing on xeric site and birch on mesic site. The maximum photosynthesis were observed at the leaf temperature range less than 25 °C in two conifers, but did not show the apparent decrease due to high leaf temperature. High photosynthetic rates in larch, pine and birch were 6 $mgCO_2/dm^2/hr$, 8 $mgCO_2/dm^2/hr$ and 15$mgCO_2/dm^2/hr$ respectively under the field conditions. The seedlings were grown at two carbon dioxide levels of 70Pa and 36Pa combined with day/night temperature of 30/18°C and 26/14°C. The height growth of seedlings ceased at 45 days for Siberian birch and at 65 days for Japanese birch under a 20−hr−day length. At high temperature regeme, maximum photosynthesis of Siberian birch was lower than that of Japanes one.

The vertical distribution of carbon dioxide concentration was measured in a birch stand mixed with larch. The carbon dioxide concentration near ground reached 600ppm at midnight. It decreased from 2 o'clock at sunrise and showed below 320ppm in early morning when the net photosynthetic rate was positive. The soil respiration rate decreased after sunrise.

Literature Cited

1) Hozumi,K. 1985 Phase diagramatic approach to the analysis of growth curve using the *u−w* diagram. Basic aspects. Bot.Mag.Tokyo 98:239−250.

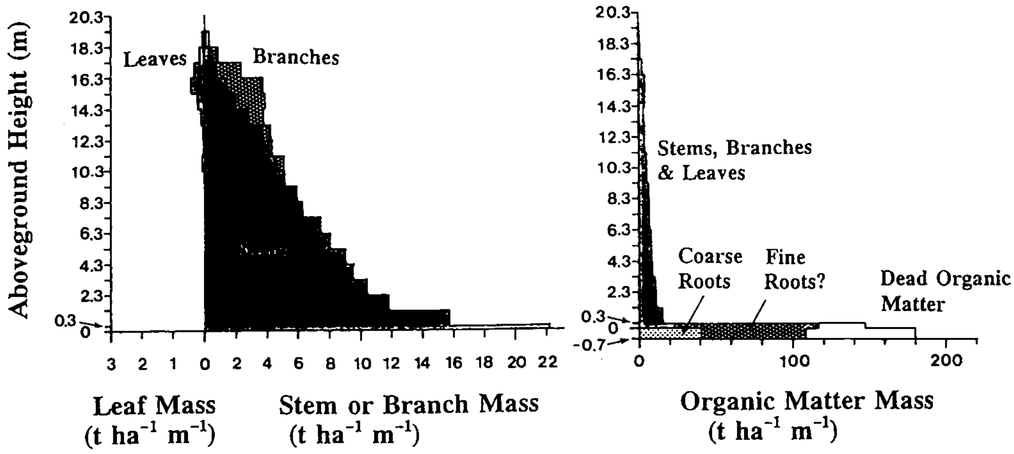
2) Satoo,T. et al 1970 Primary production in a plantation of Japanese larch, *Larix leptolepis*:a summarized report of JIPTF−66 KOIWAI. J.Jap.For.Soc. 52:154−158.

Table 1. BIOMASS OF LARIX GMELINII ECOSYSTEM

			(t/ha)[‡]	
TREE LAYER				
	Stems		114.9	
	Leaves		1.68	
		(Long-shoot leaves)		(0.018)
		(Short-shoot leaves)		(1.670)
	Branches		6.43	
		(Current long-shoots)		(0.017)
		(Others)		(6.419)
	Dead Branches[†]		0.65	
	Roots		?	
		(Coarse roots)	40.47	
		(Fine roots)	68.12?	
	Likens on trees		0.43	
SHRUB LAYER				
	Branches and Stems		0.58	
		(Current branches)		(0.002)
	Leaves		0.086	
	Dead Branches[†]		0.003	
	Coarse Roots		0.501	
HERB LAYER (EXCLUDING FOREST FLOOR)				
	Branches and Stems		0.496	
		(Current branches)		(0.035)
		(Old branches and stems)		(0.461)
	Leaves		0.942	
		(Current leaves)		(0.185)
		(Old leaves)		(0.757)
	Dead Parts[†]		0.104	
FOREST FLOOR				
	Living Plant Parts (mostly herb stems)		11.14	
	Coarse Litter[†]		10.00	
		(Stems)[†]		(3.395)
		(Branches D > 2 cm)[†]		(1.273)
		(Branches D < 2 cm)[†]		(5.332)
	Fine Litter[†]		14.92?	

[‡]Oven dry mass
[†]Necromass

Figure 1. **Vertical Distribution of Biomass and Dead Organic Matter in *Larix gmelinii* Ecosystem**



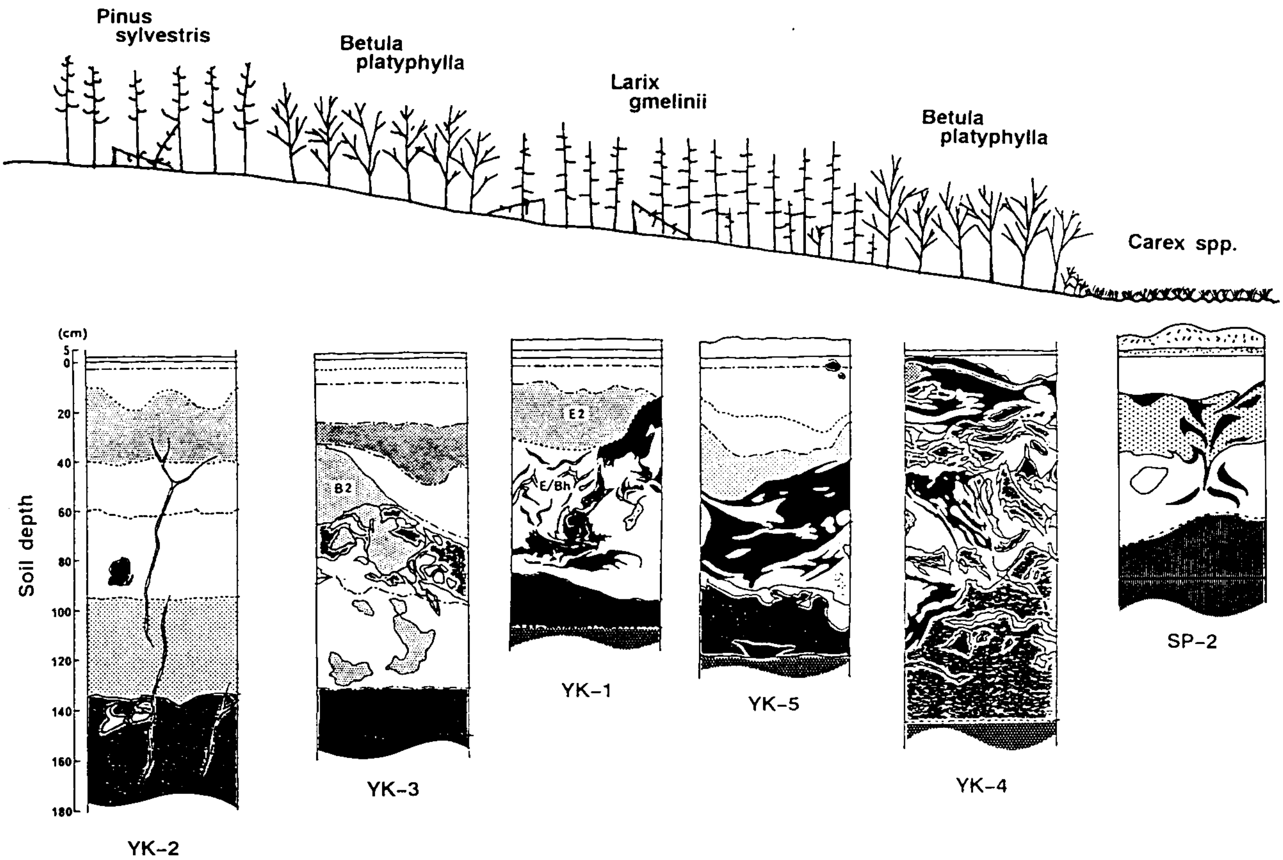


Figure 2 Schematic representation of soil catena in Spaskajapad Experimental Forest.

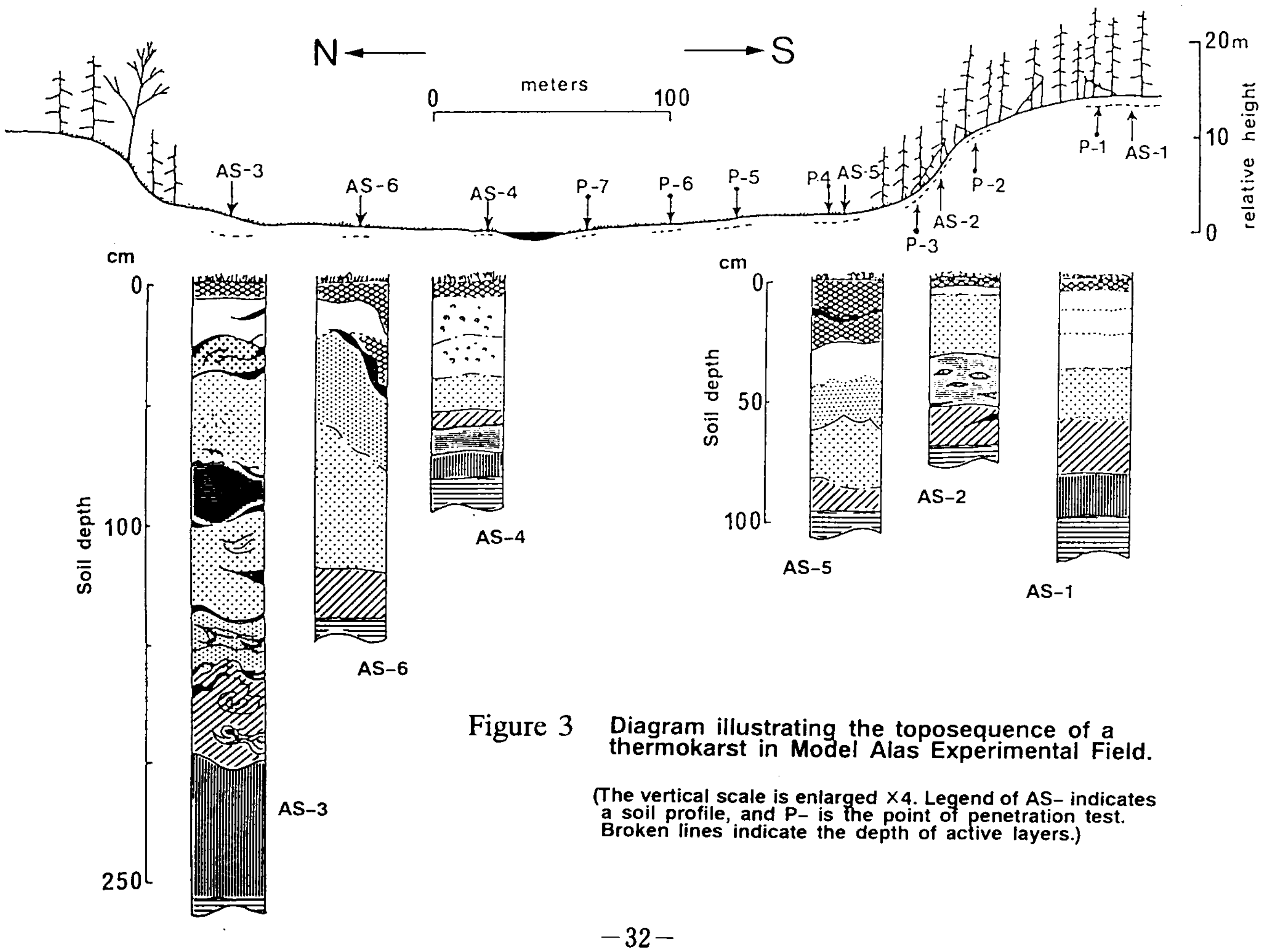


Figure 3 Diagram illustrating the toposequence of a thermokarst in Model Alas Experimental Field.

(The vertical scale is enlarged ×4. Legend of AS- indicates a soil profile, and P- is the point of penetration test. Broken lines indicate the depth of active layers.)

Table 2. Carbon and nitrogen storage in active layers at Spaskajapad Experimental Forest (the left side of the Lena River).

Profile	Vegetation	Land form	Depth of active layers		Carbon	Nitrogen
					----(kg · m^{-2})----	
YK-2	Pinus sylvestris	Upper slope	180 cm	A_0	1.43	0.03
				SOM	7.03	0.90
				Carbonate-C	0	
YK-3	Betula platyphylla	Mid slope	150 cm	A_0	0.75	0.03
				SOM	9.78	1.17
				Carbonate-C	2.27	
YK-1	Larix gmelinii	Mid slope	110 cm	A_0	1.18	0.04
				SOM	14.51	1.35
				Carbonate-C	3.33	
YK-5	Larix gmelinii	Lower slope	120 cm	A_0	2.24	0.07
				SOM	17.45	1.96
				Carbonate-C	0.17	
YK-4	Betula platyphylla	Lower slope	150 cm	A_0	0.79	0.04
				SOM	10.28	1.46
				Carbonate-C	1.19	
SP-2	Carex spp.	Flat basin	96 cm	A_0	8.43	0.84
				SOM	10.98	1.21
				Carbonate-C	4.35	

Table 3. Carbon and nitrogen storage in active layers at Model Alas Experimental Field (the right side of the Lena River).

Profile	Vegetation	Land form	Depth of active layers		Carbon	Nitrogen
					----(kg · m^{-2})----	
AS-1	Larix gmelinii	Plateau	96 cm	A_0	1.79	0.04
				SOM	4.67	0.47
				Carbonate-C	2.01	
AS-2	Larix gmelinii	Terrace scarp	66 cm	A_0	1.16	0.03
				SOM	3.92	0.27
				Carbonate-C	0	
AS-5	Potentilla, Sanguisorba spp.	Margin of basin	90 cm	A_0	3.26	0.28
				SOM	36.53	3.17
				Carbonate-C	2.25	
AS-4	Potentilla sp.	Basin (lower)	80 cm	A_0	0.39	0.02
				SOM	65.19	5.39
				Carbonate-C	6.79	
AS-6	Polygonum, Hordeum, Rumex spp.	Plain (intermediate)	137 cm	A_0	0.32	0.02
				SOM	30.21	2.39
				Carbonate-C	4.00	
AS-3	Polygonum, Artemisia, Rumex spp.	Plain (higher)	260 cm	A_0	0.12	0.01
				SOM	18.26	1.79
				Carbonate-C	15.70	