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Dissolved Organic Carbon in Coniferous Forests of Central Siberia

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Abstract

Release of dissolved organic carbon (DOC) from boreal forest ecosystems of central Siberia including permafrost, mountain and south taiga zones was compared in terms of influence of site-specific environmental conditions. *Pinus sylvestris* (southern part), *Abies sibirica* (mountain) and *Larix gmelinii* (permafrost) have different adaptational strategies and cover areas with unique hydroclimatic conditions. Among forest patterns, litter is characterized by large dissolved organic carbon DOC flux compared to that of forest floor vegetation and throughfall. Precipitation and temperature of decomposing layers were found to be the most important factors determining DOC release. Insufficient heat supply has led to a sharp decrease in extractable DOC contents in the forest floor and litter in the larch stand. DOC influx in throughfall was also important for the DOC dynamics in the organic horizon. The formation of impermeable layers of permafrost and basalt bedrock have resulted in a high DOC concentration in stream water in the watershed. Precipitation magnitude considerably affected DOC output in stream water. After long-term rainfall, DOC flux in stream water in the larch basin reached 38 $mgC \cdot m^{-2} d^{-1}$, almost 100-fold higher than that during the low flow period.

Key words: dissolved organic carbon (DOC), forest floor, coniferous forests, permafrost, central Siberia

Introduction

It is predicted that boreal forests is a significant pool and sink of carbon, especially in view of the expected climate change due to increased atmospheric concentrations of greenhouse gases (Makipaa *et al.*, 1999). It has been reported that even though climate change may increase net primary production, warmer temperatures may stimulate decomposition of organic matter, leading to a loss of carbon from ecosystems (Kirschbaum 1994, Houghton *et al.* 1992).

Generally, the estimated release of elements from organic horizons can be divided into three routes, via liquid, solid and gaseous phases, including leaching, fragmentation, and decomposer respiration, respectively (e. g. Takahashi 1996). Soluble organics is one of the important factors controlling soil processes and functioning of forest ecosystems as a whole (Dawson *et al.* 1978). This concept also suggests that DOC characteristics may be affected if dominant species of vegetation and forest floor composition are changed due to changes in forest management or global climatic conditions. Another important component of DOC research to be taken into consideration is the litter decomposition process, which is strongly affected by environmental factors such as aeration, moisture and temperature (Takahashi 1997).

In this study, we focus on water-soluble organic carbon contents in separate organic layers of the most common coniferous forests and on the effects of ecosystem heat supply and level of precipitation on DOC release. We compared several coniferous-dominated forests in terms of DOC concentrations in soil, litter, forest floor and throughfall depending on the environmental conditions of the site.

Materials and methods

1. Study sites

Three sites with different vegetation and/or slope position, as will be explained later, were used in this study. The study sites were located in three regions of Siberia based on the presence of common coniferous-dominated natural forests; Northern larch forests near Tura settlement (Evenkia), pine forests of the middle stream of the Angara river, and fir stands in the Western Sayan mountains (Table 1, Fig. 1). Descriptions of studied plant communities can be found in reports by Abaimov *et al.* (1997) and Prokushkin *et al.* (1998). Experimental plot codes are as follows (Table 2). The larch site located in central Evenkia included 4 sub-plots with different

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Table 1. Location of each study site.

Region	Dominant coniferous species	Site name	Latitude, longitude
1) Central Evenkia	*Larix gmelinii*	Larch site	64° N, 100° E
2) Middle stream of the Angara river	*Pinus sylvestris*	Pine site	55° N, 101° E
3) Northeastern part of the Western Sayan Mountains	*Abies sibirica*	Fir site	52° N, 92° E

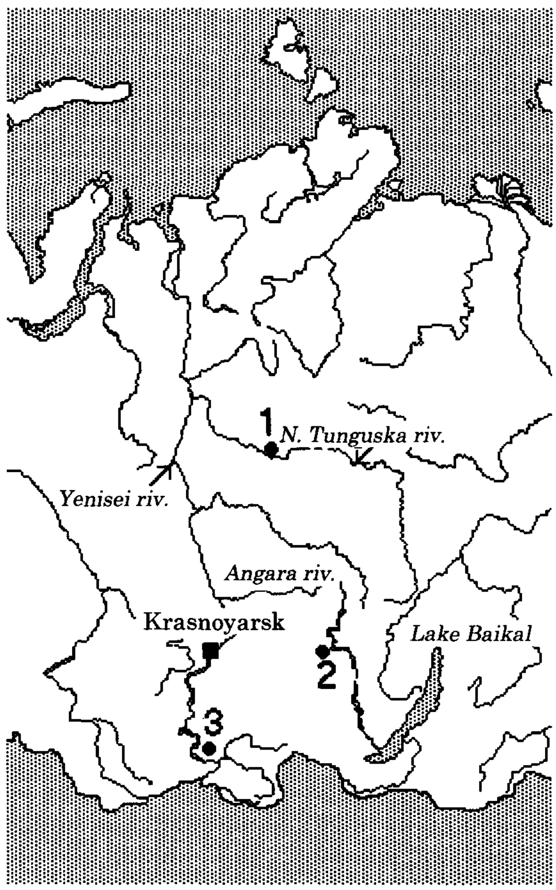

Fig. 1. Location of each study site in central Siberia.
1: Larch site in the permafrost zone (Tura),
2: Pine site in South taiga (Bratsk),
3: Fir site in Western Sayan Mountains (Tanzybey)

dominants in understory: dwarf shrub-*Sphagnum* (L-1), dwarf shrub-green mosses (L-3), dwarf shrub-green mosses with *Duschekia fruticosa* (L-4) and a burnt site (fire in 1990 (L-5)). The plots are located at different slope positions (Fig. 2 and Table 2). The pine site located at the middle stream of the Angera River also included four different understory types; dead matter (P-1), *Vaccinium* (P-2), *Alnus* (P-3) and *Vaccinium*-green mosses (P-4). The fir site located in the northeastern part of the Western Sayan mountains was differentiated by location on relief, lower slope (F-1), middle slope (F-2) and upper slope (F-3).

2. Sampling methods

2.1. General sampling design

To assess the DOC concentration and flux in the coniferous forest in central Siberia, we collected percolated water from the organic horizon, throughfall and stream water using several methods (Table 3). We also investigated the extractable DOC contents in the organic and mineral soil. Details of the sampling and analytical methods are given below.

2.2. Percolated water from the organic horizon

In the study sites, organic horizons containing dead moss and litter (hereafter termed "litter") were mostly covered by green moss-lichen (hereafter termed

Table 2. Understory species, fire history and location on the slope of each plot

Site name	Plot code	Understory	Fire hisotry	Location on slope
Larch site 1)	L-1	dwarf shrub-*Sphagnum*	unburned since 1902	Bottom
	L-3	dwarf shrub-green mosses	unburned since 1902	Middle
	L-4	dwarf shrub-green mosses with *Duschekia fruticosa*	unburned since 1902	middle
	L-5	grass-*Carex*	burnt (in 1990)	upper
Pine site	P-1	dead matter	unburned	flat
	P-2	*Vaccinium*	unburned	flat
	P-3	*Alnus* sp.	unburned	flat
	P-4	*Vaccinium*-green mosses	unburned	flat
Fir site	F-1	grass-fern	unburned	lower
	F-2	*Equsetum*-fern	unburned	middle
	F-3	*Carex* sp.	unburned	upper

1) See Fig. 2

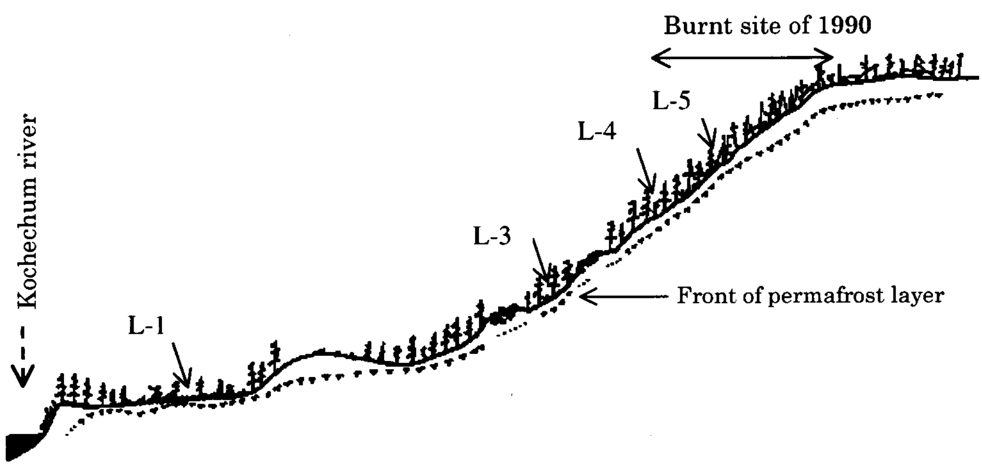

Fig. 2. Locations of studied plots on southwest facing slope in the Larch site, Central Evenkia (Tura) (adapted from Matsuura and Abaimov, 1999)

"forest floor"). We used two methods (glass vessel and activated carbon methods) to determine monthly and annual DOC fluxes from the organic horizon (Table 3). In the larch site, we installed three glass vessels (100 cm^2) each under the forest floor and litter (Fig. 5) to collect percolated water from the organic layer monthly. The percolated water in the collecting box was sampled monthly and taken to the laboratory to analyze the DOC concentration in the larch site from July to August 1998. Sampled water was dried in a water bath at 40°C to keep before DOC analysis (see 3.2). The volume of the percolated water was measured at each sampling time.

The daily DOC flux (mgC · m^{-2} d^{-1}) from each organic horizon during each sampling period was calculated using the DOC concentration (mgC·L^{-1}) in percolated water, water volume (L), collecting area of the glass vessel (100 cm^2) and the interval of sampling period (days). We also used the activated carbon method (Kaurichev *et al.* 1977) to determine the annual and monthly DOC fluxes from the organic layer (Table 3). Fifty gram of the activated carbon was placed in each collecting box to absorb DOC in the percolated water from the glass vessel, the same

Table 3. General sampling design and methods.

Sample	Method[1)]	Site (sampling interval, study period)
DOC in percolated water from forest floor and litter	Glass vessel method: sampling of percolated water from glass vessels placed under each horizon	Larch site (monthly, July-Aug. 1998)
	Activated carbon method: adsorption of DOC in percolated water collected from a vessel filled with activated carbon, Kaurichev *et al.* (1977)	Larch site (annnual, 1998-1999) Pine site (monthly, 1986-1988; annual, Aug. 1988-Aug. 1989) Fir site (monthly, June-Sep. 1992)
DOC in throughfall	Glass vessel method: sampling of throughfall collected in glass vessels located under the tree crown	Larch site (monthly, July-Aug.1998)
	Activated carbon method: as same as that for percolated water	Fir site (monthly, June-Sep. 1992)
DOC in steam water	Water sampling and discharge measurement	Larch (4-8 days, July - Aug. 1998 and 1999) Fir stand (upper and lower slope; Jun.-Sep. 1992)
Extratable DOC in organic horizon and mineral soil	Water extraction	Larch (July 1998)[2)]

1) See the text for details of each method.
2) Samples were collected within a few days at each plot.

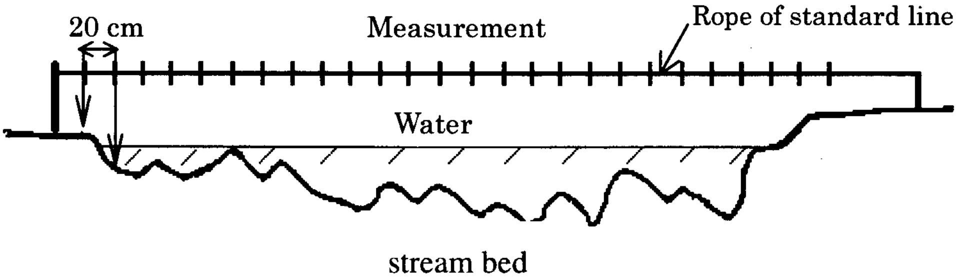

Fig. 3. Scheme of cross-sectional measurements in a stream.

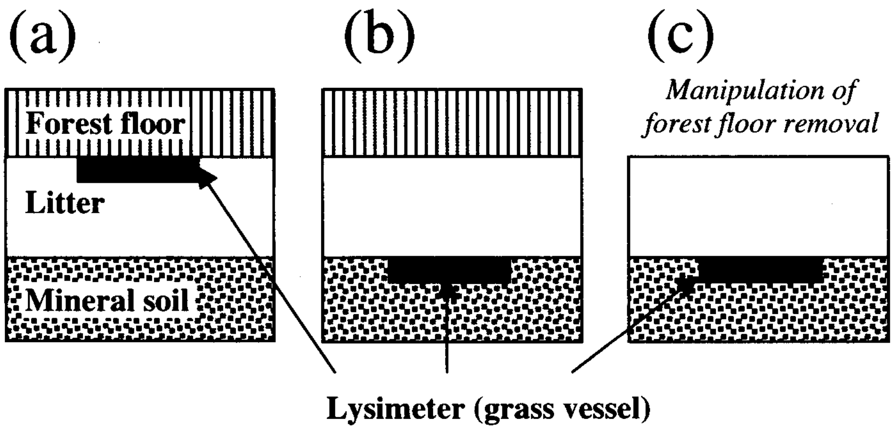

Fig. 4. Locations of lysimeters (glass vessels) under the forest floor (a) and litter (b) at the control site, and under the litter at the experimental removal plot (c).

procedure as that used for the monthly observation in the larch site as mentioned above. At the end of the observation period, the activated carbon was sampled and taken to the laboratory to analyze the DOC content in the activated carbon as mentioned below (see 3.1 and 3.2). The annual DOC flux was calculated using the absorbed DOC contents (gC) in the activated carbon, collecting area of the glass vessel ($100 cm^2$) and the observation period (year).

To understand the role of the forest floor in the DOC dynamics in surface soil, we created a manipulated plot by artificially removing the forest floor in the larch site. We installed three additional glass vessels under the litter layer at the manipulated plot (Fig. 4). The experimental removal of the forest floor was conducted near the other observations at the larch site. All of the glass vessels covered by chiffon-like materials in the control and manipulated plots were located in 2-meter transects in each site. We observed the DOC flux from the litter at the manipulated site using the same protocol as that used at the control plot in the larch site. In the larch site, we observed DOC fluxes from the litter with each type of forest floor (green mosses, *Sphagnum* mosses and green mosses/lichens) from August 1998 to August 1999.

In the pine site, we calculated the DOC fluxes during four periods to assess the seasonal fluctuation of DOC flux (see Fig.10). Only in the pine site, data on DOC flux from the litter was collected separately along with data on the degree of decomposition (L, F and F/H layer) from August 1987 to August 1988.

2.3. Extractable DOC in the organic and mineral soil

To measure extractable DOC of the forest floor, litter and 5-cm topsoil were collected from a 100 cm^2 area in three replicates in the larch site. All of the samples were dried at 80°C, weighed, and ground to pass through a 0.25-mm mesh sieve. Thereafter, 100 ml of distilled water was added to 10 g of dried sample, and the mixture was kept for 24 hours. Solutions after filtration (0.2 μm) were dried in a water bath at 40°C to store before analysis (see 3.2).

2.4. Throughfall

To collect throughfall, two glass vessels (100 cm^2) were placed under the crowns (in north and south directions, respectively) in all of the experimental plots in the larch and fir sites and under *D. fruticosa* and larch seedlings in the post fire plot (L-5) in three replicates. We measured the tree numbers per area and crown diameter of each tree and seedling at each observation site (Abaimov *et al.* 1997, Abaimov *et al.* 1998).

2.5. Stream water

Stream water was collected and analyzed for DOC concentration to assess the DOC flux of stream water at one site in the Tura Basin (41 km^2) located in the larch site and at two sites (upper and lower positions of the studied slope) in the Tanzybey Basin (basin areas not available) in the fir site (Photo. 1~3). Two hundred and fifty ml of collected water was dried in a water bath at 40°C for DOC analysis (see 3.2). We measured stream water level, velocity and topography of the streambed at 20-cm intervals at each sampling time to calculate the water discharge (Fig. 3). DOC flux of stream water was calculated from DOC concentration, water discharge and basin area.

3. Analytical method for DOC concentration

3.1. Extraction from activated carbon

Elution of organic matter from activated carbon was carried out separately for "simple" organics (organic acids, aminoacids, carbohydrates, etc.) and for "specific" organic matter (fulvic and humic substances). Ten gram of activated carbon was placed in columns (∅ 2.5 cm) in 3 replicates. Extraction of simple organics was carried by 75 ml of 80 % acetone (30 $ml \cdot hr^{-1}$) followed by 75 ml of distilled water at the same velocity of elution. Acetone and water eluates were mixed and dried in a water bath at 40°C. After that, fulvic and humic substances were extracted by 50 ml of 1 % ammonium hydroxide (NH_4OH; namely 30 $ml \cdot hr^{-1}$) followed by 100 ml of distilled water at the same velocity of elution. Elutes were also mixed and dried (Kaurichev *et al.* 1977).

3.2. Determination of DOC content in the prepared dry samples.

Before analyses, dried samples were washed in a total volume of 50 ml of distilled water. Depending on the carbon content of the sample for analysis, 2-5 ml of prepared solution was used. This volume was dried in a water bath at 40°C. The sample was then washed with 5 ml of 0.1 n $K_2Cr_2O_7$ in 50 % sulphuric acid and incubated in closed vessels at 105°C for 30 min. The next steps were 8-hr incubation at 22°C, addition of 10 ml of distilled water, storage at room temperature for 30 min, and measurement of optic density of the final 15 ml solution at 590 nm using a colourimeter KFK-3 (Russia). Calibration was fulfilled using standard saccharose solutions. The average deviation in analysis of 1.0-0.1 mgC is 1.6% (0-5.9%); the accuracy of the method is about 0.43% when the variation coefficient is 0.5% (Diakonova 1977). We worked within these limits (0.1 – 1.0 mgC) using 2-5 ml of sample for analysis depending on the DOC concentration.

Results

1. Larch site

In the larch site, mean daily DOC fluxes from the forest floor and litter were related with their slope positions. Namely, the maximal amount of DOC flux was found in the upper slope (Fig. 5). The difference between the DOC fluxes at the lower and upper slope sites was about 20%, depending on the layer. DOC flux from the litter at the L-5 plot (burnt site) was the smallest among the plots examined. Artificial removal of the forest floor increased the DOC fluxes from the litter layer in all plots in the larch site (Fig. 5).

DOC flux in throughfall also varied with the position of the slope (Fig. 6), from 0.3 to 0.6 $mgC \cdot m^{-2} d^{-1}$. The crown area at the lower position of the slope (L-1) tended to be smaller than that at the upper positions. DOC fluxes in throughfall of dead standing larch, seedlings (eight years old) and *Dushekia fruticosa* were about 37-51 % of the throughfall of live larch (Table 4).

Extractable DOC storage in the forest floor and litter increased with increase in the elevation of the slope, although the L-5 plot (burnt site) had the least

Photo. 1. A view of the watershed in Tura, central Siberia.
The right side was burnt by the forest fires.

Photo. 2. Stream view of study site toward the origin

Photo. 3. Measurement point of the water flow of stream.
Color of water was dark brown. The rope is the standard line.
A person in this photo. is the first author of this article.

Table 4. Daily DOC fluxes in throughfall under various crowns in the L-5 plot in the larch site from July to August 1998.

Vegetation	Mean	SE[1)]
	$mgC \cdot m^{-2} d^{-1}$	
Live larches	0.60	0.09
Dead larches	0.37	0.02
Larch seedlings	0.26	0.02
D. fruticosa	0.30	0.03

1) Standard error

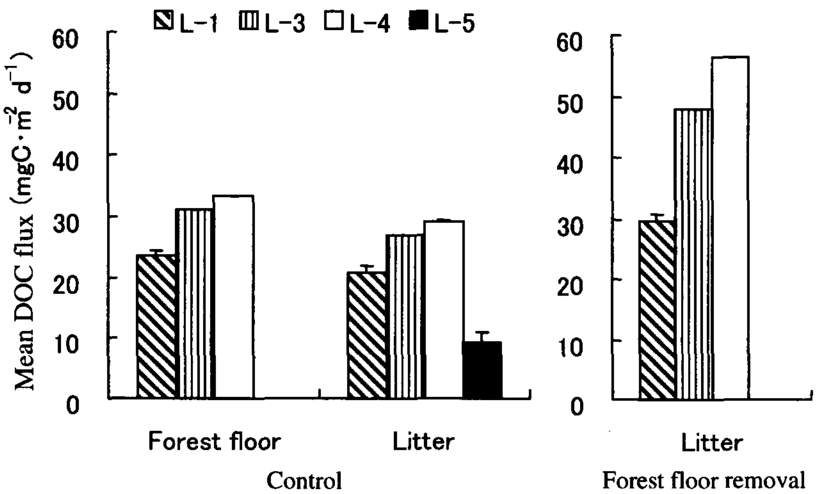

Fig. 5. Daily mean DOC fluxes from the forest floor and litter at the control site (left) and manipulated site (right) in the larch site from July to August 1998. Samples were collected in the glass vessels. There was no forest floor in plot L-5 in the control site. Each bar on the box represents the standard error.

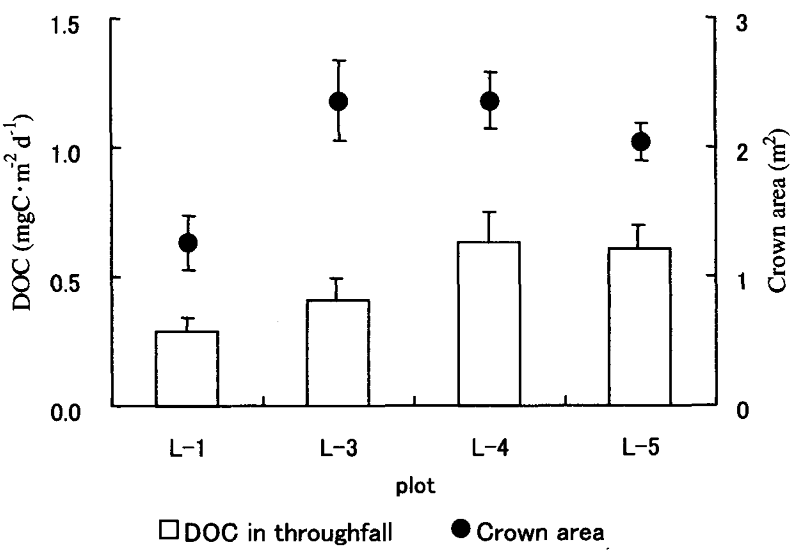

Fig. 6. Daily mean DOC fluxes in throughfall and crown area in each plot in the larch site from July to August 1998. DOC in throughfall was collected using glass vessels. Each bar on the box represents the standard error.

Table 5. Annual DOC fluxes (August 1998 - August 1999) of throughfall and percolated water from the forest floor, and water extractable DOC storage in the forest floor in each plot in the larch site. Numbers in parentheses are standard error.

Plot	Throughfall[1]	Percolated water			Extractable DOC
		Green mosses	*Sphagnum* mosses	Green mosses and lichens	
	Annual flux (gC·m^{-2} y^{-1})				Storage (gC·m^{-2})
L-1	5.4	6.4 (0.6)	5.7 (0.5)	1.8 (0.3)	11.6 (0.8)
L-3	6.1	6.1 (0.7)	NA[3]	6.4 (0.7)	16.2 (0.9)
L-4	8.8	9.1 (0.8)	NA[3]	6.8 (0.8)	17.4 (0.1)
L-5	2.2	NA[2]	NA[3]	NA[2]	0.5 (0.1)

1) Water volume of throughfall was calculated from the sampled volume (L) and the crown area (m^2).
2) Data are not available (NA) because *Sphagnum* species did not exist in the plot.
3) Data are not avalilable because it was too difficult to separately estimate green mosses from the other vegetation.

Table 6. Water discharge and DOC concentration, and flow and flux in stream water in the Tura basin (41km2) including the larch site from July to August 1998.

Date	Water		DOC		
	Discharge	Yield	Concentration	Flow	Flux
unit	m^3· s^{-1}	mm·d^{-1}	mgC·L^{-1}	kgC·d^{-1}	mgC·m^{-2} d^{-1}
July 18	0.025	0.05	8	17	0.4
July 24	0.142	0.30	6	74	1.8
August 3	0.710	1.50	9	552	13
August 6	1.231	2.59	11	1170	29
August 8	0.158	0.33	5	68	1.7

DOC storage among the plots examined (Fig 7). There was no significant difference in extractable DOC storage in 5-cm top soil among the plots. Annual DOC input by throughfall to the forest floor was comparable to the annual DOC fluxes from the various forest floors in the larch site (Table 5). This input of DOC by throughfall corresponded to 38-51 % (unburned site) and 440 % (burnt site) of the extractable DOC in the forest floor (Table 5).

DOC flux in stream water ranged from 0.4 to 38 mgC·m^{-2} d^{-1}, depending on precipitation magnitude (Fig. 8 and Table 6), in the summers of 1998 and 1999 from larch ecosystems covering a 41-km^2 area of watershed. At the same time, carbon concentration did not drastically vary; they were 5-11 mgC·L^{-1} in 1998 (Table 6) and 11-24 mgC·L^{-1} in 1999 (Fig. 8).

2. Pine site

Annul precipitation at the pine site from 1986 to 1988 ranged from 352 to 444 mm·y^{-1} (Fig. 9). Fig. 10 shows the seasonal fluctuation in DOC fluxes from the litter at the pine site. Autumn and spring were characterised as periods of highest DOC releases (Fig. 10). During summer, total DOC released from the litter was considerably lower than that during autumn and spring (Fig. 10). However, DOC release in summer was uniform, and monthly fluctuations were in the range of 1-2 gC · m^{-2}. The level of precipitation in summer was one of the critical factors influencing DOC leaching from litter (Figs. 9 and 10). It was found that higher precipitation induced an increase in DOC release in experimental plot P-4 up to 15 gC·m^{-2} period^{-1}. Fig. 11 shows annual DOC fluxes from the litter in each plot in the pine site from 1986 to 1987. Annual DOC flux in the P-1 plot was the largest in all plots in the pine site (Fig. 11). In the P-1, 2 and 3 plots, transport of DOC with percolating water to lower horizons from the litter during summer accounted for about 32 % of the total annual DOC release, although the quantity in the P-4 plot was only 19%.

Fig. 12 shows the annual DOC flux from each layer in the litter in each plot in the pine site. The P-3 (*Alnus* sp.) and 4 (*Vaccinium*-green mosses) plots showed the highest quantities of annual DOC flux (6 to 38 gC·m^{-2} y^{-1}) from the litter. In the P-1 (dead organic matter in forest floor) and P-2 (*Vaccinium* pine stands) plots the quantities of annual DOC flux from the litter were lower than those in the P-3 and 4 plots.

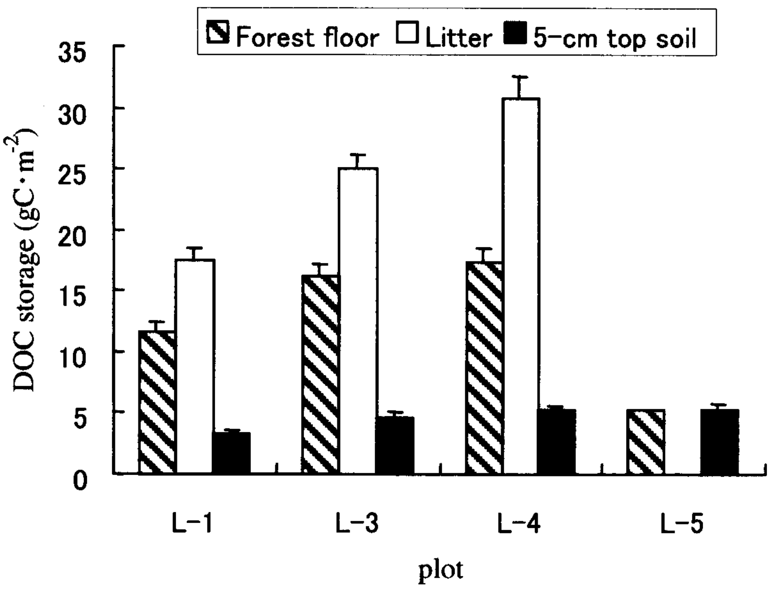

Fig. 7. Extractable DOC storage in the litter at the larch site (July 1998). Each bar on the box represents the standard error.

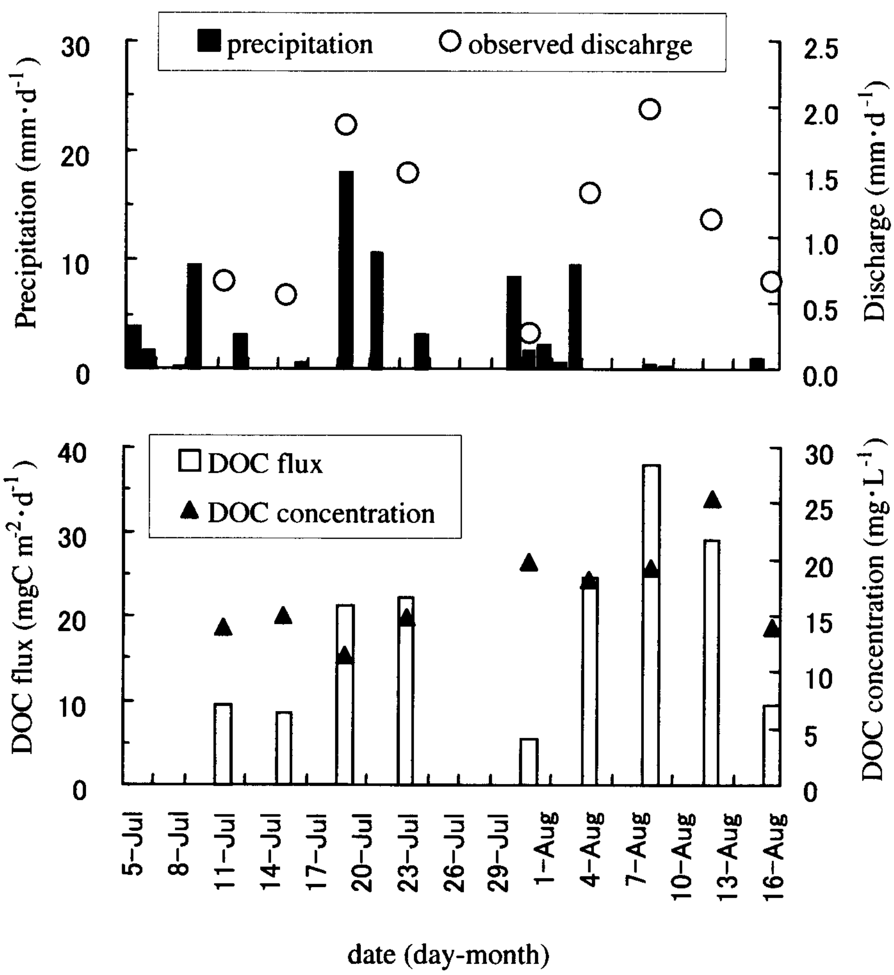

Fig. 8. Daily precipitation, stream discharge (upper), DOC flux and concentration in stream water (lower) at the larch site from July to August 1999.

3. Fir site

The release of DOC from the litter with percolated water in the lower slope plot (F-1 plot) was higher than that in the middle and higher slope plots (F-1 and 2 plots) in the fir site (Fig. 13), although DOC flux from the upper position of the slope was less than the DOC fluxes from the upper positions at the larch site (Fig. 5). DOC flux in throughfall in the fir site showed also same tendency as the DOC in percolated water from the litter (Fig. 13). DOC release from the fir crown in the lower position (1.2 mgC·m^{-2} month^{-1}) was 2-fold higher than the DOC in throughfall of the fir growing near the glacier at a higher position (0.5 mgC·m^{-2} month^{-1}). Fir forests in mountains also have considerable losses of carbon-containing substances. Total DOC flux in stream water from June to September ranged from 17 mgC·m^{-2} in the stream of the upper slope fir stands to 19 mgC·m^{-2} in the stream of the lower slope fir stands.

Discussion

There are several reports describing the importance of DOC as an intermediate component between the atmosphere, live phytomass and humus (Kononova 1963, Kauricheva and Yashina 1991, Prokushkin and Kaverzina 1988). It has also been shown that such organic matter can play multiple roles in stand organization as an allelopatic agent, nutrient source, etc. (Lukina 1984, Vedrova 1995).

The results of our series of experiments showed that the quantity of extractable DOC in the components (forest floor, litter and 5-cm topsoil) varied from site to site. The most evident differences were found between organic layers. Figures 8 and 12 show that litter releases maximal values of DOC (both flux and extractable form), which are 20-200% higher than those from the forest floor and 5-cm topsoil. However, we also found that removal of the moss-lichen cover and, to a lesser extent, litter led to an increase in DOC release (Fig. 5). Artificial removal of the forest floor increased DOC about by 1.1- to 2-fold more than in the control site. The most likely reason for this is that temperature increased both on the surface and in the humus layer and accelerated decomposition.

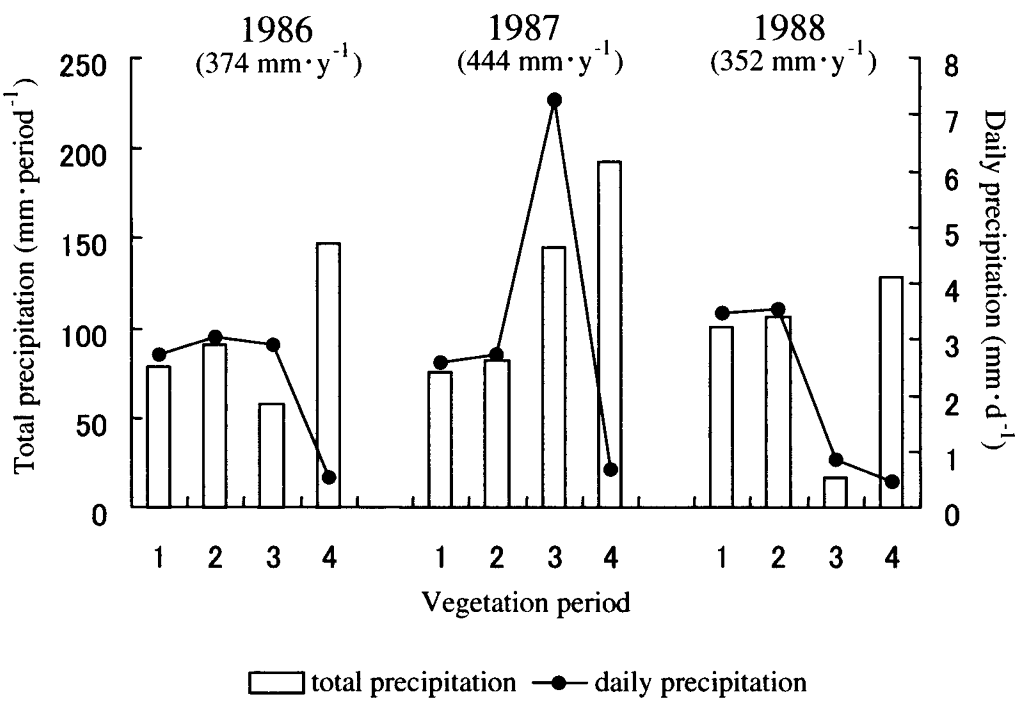

Fig. 9. Seasonal fluctuation of total and daily precipitation in each vegetation period in the pine site from 1986 to 1988. Annual precipitation in each year is shown in the figure.
Vegetation period: 1: June 21 - July 20 (29 days)
2: July 21 - August 20 (30 days)
3: August 21 - September 10 (20 days)
4: September 11 - June 20 (282 days)

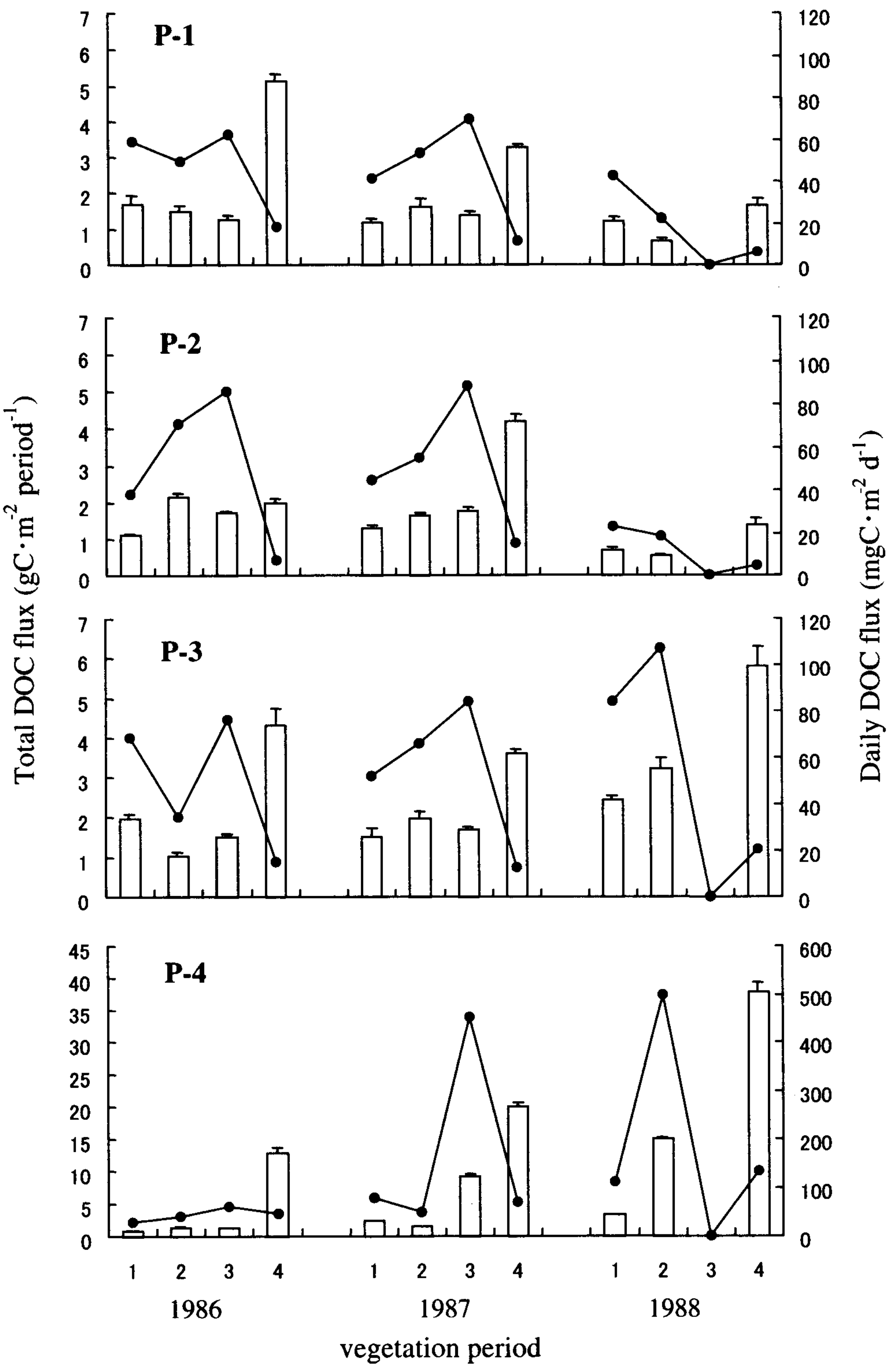

Fig. 10. Seasonal fluctuation of total (□) and daily (●) DOC fluxes from the litter layer in each vegetation period in each plot in the pine site using the monthly activated carbon method from 1986 to 1988. Note that the Y-axis of P-4 (bottom) is different from the others. Each bar on the box represents the standard error.

Vegetation periods; **1**: June 21 - July 20 (29 days)
2: July 21 - August 20 (30 days)
3: August 21 - September 10 (20 days)
4: September 11 - June 20 (282 days)

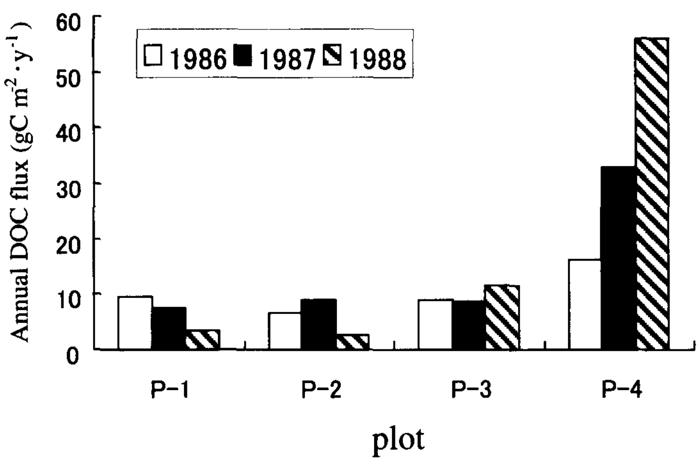

Fig. 11. Annual DOC flux from the litter layer in each plot in the pine site using the monthly activated carbon method from 1986 to 1988. Each bar on the box represents the standard error.

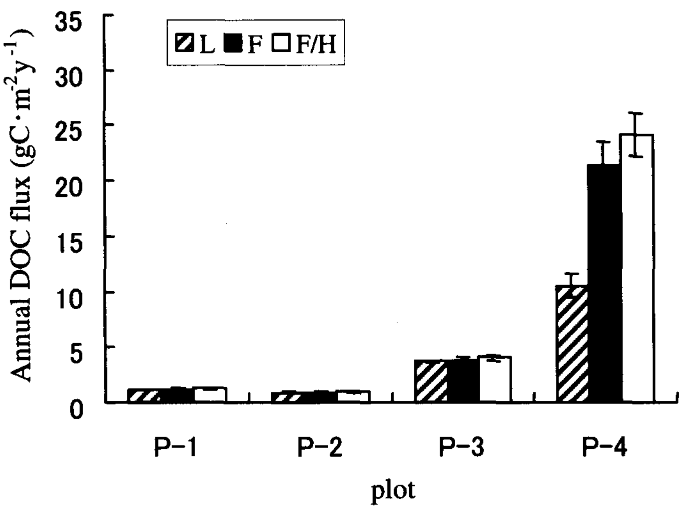

Fig. 12. Annual DOC flux from each layer in the organic horizon in each plot in the pine site using the annual activated carbon method from August 1988 to August 1989. Each bar on the box represents the standard error.

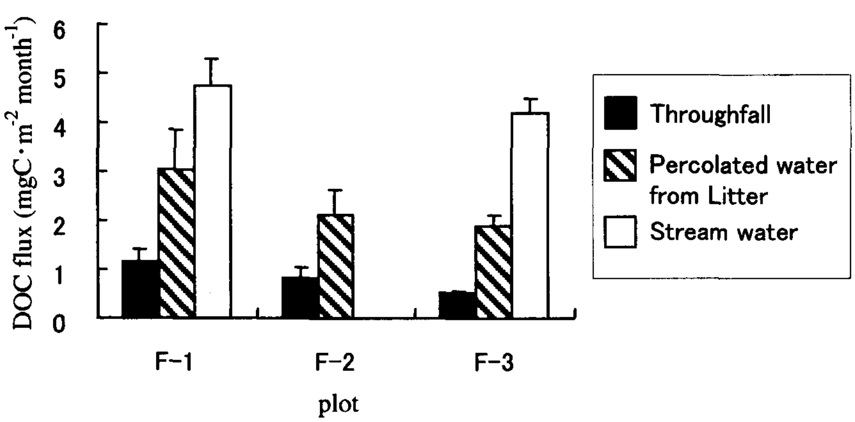

Fig. 13. Mean DOC flux in throughfall, percolated water from litter and stream water in each plot in the fir site from June to September 1992. Stream water was not observed in F-2 plot. Each bar on the box represents the standard error.

Another feature of DOC fluxes in the pine forests of central Siberia is the significant effect of hydroclimatic conditions in the litter layer. Analysis of the intensity of DOC leaching from upper litter layers during summer showed that the highest release occured in pine stands (*Alnus*, *Vaccinium* and dead organic matter) characterized by higher temperatures of litter (Fig. 10). In general, the development of moss cover acting as a heat insulator tends to cause a decline in temperature and decrease in DOC flux from the organic horizon (e.g., *Vaccinium*-green mosses stand, P-4 plot). However, the annual DOC release in the P-4 plot was 3~10-times higher than that in other plots in the pine site (Fig. 11). The main reason for this is thought to be the specific chemical composition of green moss litter and the increased microbial activity in such types of litter in spring and autumn, when 30% of precipitation occurs.

In the Evenkia larch site, there was a decrease in the moss-lichen cover development (from 35-45cm to 7-15cm) along the southwestern facing slope from the waterlogged terrace to the upper part, resulting in more favourable edaphic conditions in the middle and upper positions. Green moss larch stands in the middle and upper slopes (plots L-3 and L-4), having higher temperatures in decomposing layers, showed the highest DOC in leachates from the forest floor and litter (Fig. 5). Under the unfavorable colder conditions in Evenkian larch stands (*Sphagnum* site, L-1 plot), extractable DOC contents in litters and DOC flux from the organic horizon were 30-80% less than those in stands with less-developed moss-lichen cover (forest floor) and consequently a better hydroclimatic environment. Litter in the forested areas in the upper alpine region of Western Sayan mountains contains a smaller amount of DOC than those litter at the lower slope position. This difference appeared to be caused by permafrost and consequently lower temperatures in decomposing layers. Higher heat supply in the lower slope site resulted in a 2-fold increase in the DOC release from litter (Fig. 13).

The post-fire plot (L-5) with a thin forest floor (1-2 cm), which had been destroyed by fire in 1990, showed the lowest DOC flux among the litters in all stands (Fig. 5).

In contrast to our data obtained from the larch site, total soil organic carbon (SOC) at the same positions shows highest values in the flat waterlogged *Sphagnum* larch stand located at the lower slope (Matsuura and Abaimov 1999).

The DOC flux in throughfall from the larch canopy showed a slight positive correlation with the development of tree crown (Fig. 6). The mature larch trees of green moss-dwarf shrub communities (L-3 and 4 plots) and the trees that survived in the post-fire plot (L-5) are characterised by well-developed crowns. DOC flux in throughfall of dead larch trees, larch seedlings and *D. fruticosa* assessed in the burnt site in Evenkia was comparable with that in mature living trees in the *Sphagnum* experimental plot, where development of larch tree crowns was very slow. Dead larch trees in the post-fire plot (L-5) may have contributed substantially to the total input of DOC to soils. In the case of mountain fir taiga, we found tremendous DOC flux in throughfall, which are comparable even with DOC flux from the litter (Fig. 13). In general, flux of dissolved carbon from canopies shows intense excretion activity of conifer species studied (larch and spruce) and may reflect the allelopatic effect on understory plants.

A study of DOC output from a watershed carried out in Evenkia and Western Sayan showed that this pathway of the carbon cycle can play a significant role in DOC dynamics in a basin. In Evenkia, northern cryogenic soils and basalt bedrock in mountain regions create peculiar environmental conditions, where impermeable layers close to the surface enhance output of DOC from ecosystems. The main cause of the large loss of DOC from ecosystems in such an environment is the existence of an impermeable layer of basalt bedrock or permafrost. Thus, surface water carries considerable quantities of organic matter released from a watershed area. DOC discharge from a 41-km^2 watershed area varied greatly day by day, ranging from 0.4 to 38 $mgC \cdot m^{-2} d^{-1}$, depending on the year (Fig. 8 and Table 6). Taking into account the fact that DOC concentration in stream water had only 2 time shifts, from 6 up to 11 $mgC \cdot L^{-1}$ in 1998 and from 11 up to 24 $mgC \cdot L^{-1}$ in 1999, after rainfall, we can conclude that precipitation magnitude plays a very important role in total DOC output of stream water.

It should be emphasized that substantial losses of organic matter occur as a result of its movement above impermeable layers with rainfall water percolated through the forest floor, litter and thin active soil horizons. DOC measurements in stream water together with measurements of CO_2 emissions by vegetation and soil respiration could assessed quantitative characteristics of outward carbon flux and provide insights for a better understanding of forest ecosystem structure and response to disturbances.

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