# Comparative study on soil carbon storage of permafrost ecosystems in Northeastern Eurasia

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## 1. INTRODUCTION

Distribution of forest ecosystem on continuous permafrost is limited on northeastern Eurasia, including eastern and central Siberia. The main tree genus in the continuous permafrost region is *Larix* (*L. gmelinii* in central Siberia and *L. cajanderi* in eastern Siberia). This unique ecosystem, the couple of forest and continuous permafrost, has not been recognized, and rather been regarded as an exception or minor portion of uniform boreal forest. Typical stereotyped description for boreal forest ecosystem is that the boreal forest develops on nutrient poor podzolic soils and organic soils in waterlogged environment (for example, Jarvis et al. 2001). But, forested area occupied by podzolic and organic peaty soils is very rare in central and eastern Siberia.

The environmental condition and permafrost distribution shows distinct boundary at the Yenisey River (Tuhkanen 1984, Brown et al. 1997). Evergreen coniferous ecosystem occupies from Europe to the West Siberia wetland, whereas from the boundary of the Yenisey River, deciduous coniferous ecosystem extends eastward to Kolyma lowland (Abaimov et al. 2000). This deciduous conifer *Larix* forest ecosystem has unique ecological features which we did not find at non-permafrost ecosystems (Kajimoto et al. 1999, 2003, Osawa et al. 2003, Matsuura et al. 2005). This paper shows briefly the regime of soil organic carbon storage and C/N ratio in permafrost larch forest ecosystems of central and eastern Siberia, of which parameters were quite different from expected values compared to other boreal ecosystems in non-permafrost region.

## 2. STUDY SITE AND METHODS

Twenty-four profiles in eastern Siberia and eleven profiles in central Siberia were surveyed. Survey points located on the area ranging from 62° to 72° N latitude, from 125° to 160° E longitude in eastern Siberia, and from 64° to 68° N latitude and from 96° to 100° E longitude in central Siberia (Table 1).

### 2.1 Soil profiles in eastern Siberia

Twelve profiles among 24 were surveyed in Yakutian Basin, where thermokarst depression topography (alas) developed on the opposite side of Yakutsk. Rest of twelve profiles were surveyed in forest tundra transition zone in lower Lena River (see Photo 1), Kolyma lowland, and mountain forest tundra at upper Indigirka River. Soil parent material of forested area in Yakutian Basin was old fluvial deposit with sandy texture. Soils in thermokarst depression derived from lacustrine deposit. Soil profiles in thermokarst depression showed alkaline pH, carbonate accumulation, and distinct cryoturbation (see Photo 2). Soils of forest tundra in

Symptom of Environmental Change in Siberian Permafrost Region,
Eds. Hatano R and Guggenberger G, p 103-107, Hokkaido University Press, Sapporo, 2006

**Table 1.** Site name and approximate coordinates of soil survey points and their ecological features.

| Site name | Lat. N | Long. E | Vegetation | Topography | Profile($n$) |
|---|---|---|---|---|---|
| *Eastern Siberia* | | | | | |
| Spaskayapait | 62°15' | 129°37' | larch, birch, pine, grassland | flat | 6 [a] |
| Tungulu | 62°09' | 130°38' | larch, grassland | flat | 6 [a] |
| Koldayurakh | 71°37' | 125°31' | larch forest tundra | terrace, slope | 7 [b] |
| Plakhino | 68°41' | 160°16' | larch forest tundra | terrace | 4 [c] |
| Oymiyakon | 63°11' | 145°02' | larch mountain forest tundra | slope | 1 [d] |
| *Central Siberia* | | | | | |
| Tura | 64°19' | 100°14' | larch | slope | 10 [e] |
| Yakutali | 66°46' | 97°18' | larch forest tundra | table top | 1 [f] |

[a] Matsuura et al. (1994), [b] Matsuura and Yefremov (1995), [c] Matsuura et al.(1999), [d] Matsuura et al. (1997), [e] Matsuura and Abaimov (1998, 1999), [f] unpublished data.

northern transition zone derived from fine texture fluvial deposit. Soil parent material of mountain forest tundra in upper Indigirka was fragmented weathered rock.

### 2.2 Soil profiles in central Siberia

Soil survey was conducted intensively in larch forests near Tura along Kochechom River (see Photo 3). Most soil profiles showed neutral to slightly acidic, but soils located on south facing slope showed alkaline pH and carbonate accumulation in subsoil. One profile was located on forest tundra transition zone in Putorano

**Photo 1.** Forest tundra transition zone in lower Lena River. Polygon formation indicates ice-rich permafrost.

**Photo 2.** Strong cryoturbation observed in active layer. This profile surveyed at the thermokarst depression

Mountains (see Photo 4). Soil parent material was weathered basalt rock fragment.

**Photo 3.** Mature larch forest ecosystem in central Siberia with high earth hummocks.

### 2.3 Soil organic C and N storage estimation in active layer

Soil profiles were surveyed to the permafrost table or bedrock surface, and samples for bulk density, SOC and N were taken in each horizon with 100 $cm^3$ stainless core sampler. Soil total C and N were determined using 2-mm sieved fine earth, by dry combustion method (SUMIGRAPH-NC800). If soil samples showed HCL effervescence, carbonate-C was separately determined by volumetric method (Allison and Moodie 1965). SOC contents were calculated by subtracting carbonate-C from total C contents.

**Photo 4.** Landscape of forest tundra transition zone in Putorano Mountains, central Siberia.

## 3. RESULTS AND DISCUSSION

### 3.1 Soil organic carbon (SOC) storage

Soil organic carbon (SOC) storage varied much among soils in both eastern and central Siberia. SOC storage regime and average SOC storage in active layer were larger in eastern Siberia (average; 16.8 kgC $m^{-2}$ in eastern Siberia and 6.4 kgC $m^{-2}$ in central Siberia). Soils of thermokarst depression showed much SOC storage, with relatively large accumulation of carbonate-C in active layer. Soil profile developed on earliest dried-up terrace in the thermokarst showed highly carbonate-C accumulation. Soils in northern forest tundra zone did not contain carbonate-C in active layer. Such alkaline soil development is due to extreme continental climate condition in Yakutian Basin with low annual precipitation.

Because soils of central Siberian larch forests had much gravel content compared to eastern Siberian soils, SOC storage in central Siberian soils was mush less than those of eastern Siberia. Soil profiles located on south-facing and post-fire regenerating site showed slightly alkaline pH. Soil profiles located on mature larch forests and north-facing slope did not have any features of carbonate-C accumulation in active layer. Estimated carbonate-C accumulation in central Siberian soils was one order of magnitude smaller than those of eastern Siberian soils.

### 3.2 Soil C/N ratio

Whole active layer soil C/N ratio regime was quite different between eastern and central Siberia (Fig. 1). Average C/N ratio of soils in eastern Siberia was about 14, whereas higher average C/N ratio was estimated in central Siberia (average C/N = 20). Post et al. (1982) reviewed carbon storage and C/N ratio according to the climate gradient. They concluded that northern ecosystem soil C/N ratio was around 20 and that C/N ratio was higher than that of temperate ecosystems. Average C/N ratio of central Siberian soils is reasonable, but the average C/N ratio of eastern Siberian soils is within anomalous regime as boreal ecosystems.

Although the climate in Yakutsk is more continental and extreme than that of Tura, climate in both eastern and central Siberia is the same extreme continental with low annual precipitation (200 – 350 mm) and large temperature differences. The critical factor affecting soil C/N ratio may be the difference of soil parent material between eastern and central Siberia. Soil parent material of eastern Siberia is fluvial/alluvial or lacustrine deposit, having been developed during Pleistocene and Holocene by large river system. On the other hand, in central Siberia, soil parent material in Central Siberian Plateau is weathered rock fragments derived from old lava basalt. The difference between parent materials (deposit-origin vs. bedrock-origin) may be important factor which control nutrient accumulation/decomposition system in a given environmental conditions.

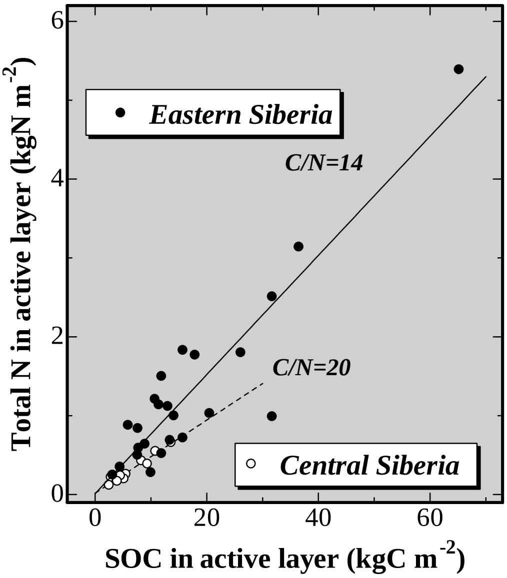


**Fig. 1.** The relationship between SOC and total N of 35 surveyed soil profiles.
Solid circles; eastern Siberia.
Open circles; central Siberia.
Solid line indicates C/N=14 for eastern Siberian soils, and dashed line C/N=20 for central Siberian soils.

## 4. CONCLUSION

Deciduous conifer, larch, ecosystems occupy on continuous permafrost in northeastern Eurasia. This unique ecosystem showed distinct features than expected according to the stereotyped view of boreal forest. The average SOC storage in active layer was different between eastern and central Siberian soils. Soil of eastern Siberia, which derived from fluvial/alluvial or lacustrine deposit showed much SOC storage with lower C/N ratio. Different average C/N ratio between eastern and central Siberia suggested that differences in soil parent materials might affect nutrient storage.

*Acknowledgements.* I thank all of Russian researchers of Institute for Biological Problems of Cryolithozone in Yakutsk, and Sukachev Institute of Forest in Krasnoyarsk, for their cooperative field survey and logistic support. I also thank all of Japanese colleagues who joined this research activity during almost ten years together.

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