カナダ永久凍土の炭素蓄積量に対する凍結かく乱と排水条件の影響

藤井一至 [1]，松浦陽次郎 [1]，安江恒 [2]，大澤晃 [3]
[1] *森林総合研究所*
[2] *信州大学*
[3] *京都大学*

Effects of cryoturbation and drainage on organic matter storage in Canadian permafrost soil

Kazumichi Fujii[1], Yojiro Matsuura[1], Koh Yasue[2], Akira Osawa[3]
[1]*Forestry and Forest Products Research Institute*
[2]*Shinshu University*
[3]*Kyoto University*

Introduction and objectives: Permafrost soils store the large amounts of organic matter. The soil organic C (SOC) storage can be enhanced by cold climate, flooding, and input of recalcitrant litters. In black spruce forests, cryoturbation of Mackenzie area can typically develop mounds and troughs called hummocky micro-topography. This process is hypothesized to play roles in enhancing SOC storage, however, history and functions of hummock soils in SOC accumulation are still unclear. Development of hummock soil structure could induce tree tilting, as black spruce trees typically grow on the shoulder of hummocky soil. Tree rings could record tilting and soil hummock dynamics (Fig. 1). Using tree ring analyses and litter decomposition experiments, we attempted to reconstruct hummocky soil dynamics and their effects on SOC storage.

Materials and methods: To analyze environmental factors regulating SOC storage, we compared soil C stocks in BSF black spruce forest (BSF) with those in tundra (TND) on fluvial sediments and white spruce forest (WSF) on the upland soil derived from glaciofluvial sands in Northwest Territories, Canada. The following environmental parameters were also measured: soil temperature and moisture, aeration index [Eh, reducible iron (Fe) oxides] of soils, and the decomposition rates of litters (lichen, moss, and root litters) buried in the soils. To reconstruct the history of soil hummock formation, tree ring widths were measured year by year. The magnitude of tree tilting was calculated by the maximum tree ring width dividing by the minimum tree ring width.

Results and Discussion: The BSF exhibited the larger SOC stocks than TND and WSF. The annual mass loss rates of lichen and moss litters were consistently small at all sites. The development of hummocky soil micro-topography resulted in accumulation of sparingly-decomposable lichen litters in mounds and accumulation of moss litters in troughs. Tree ring analyses suggested that hummock soils were formed through freeze-thaw cycles over 200 years. The thick layers of lichen and moss litters in BSF appeared to limit deep melting of permafrost soil during summer. Soil water dynamics indicated that seasonal flooding events caused by spring snowmelt and permafrost melting in summer. Rapid snowmelt and water percolation enhanced aeration in sandy WSF soil, while BSF soils were saturated by water flooding on impermeable permafrost table. The redox cycles of iron were recorded as accumulation of oxalate-extractable Fe oxides. The SOC stocks in BSF and TND soils were significantly ($p < 0.05$) greater than in WSF soil. There was a positive correlation between SOC stocks and free Fe oxides. Cold climate and poor drainage, which are imposed by hummock soil structure, contribute to the largest SOC stocks in black spruce forests.

Conclusion: Tree ring analyses suggested that the hummocky soil micro-topography could be formed by freeze-thaw cycles over 200 years. Development of hummocky micro-topography accumulates lichen and moss litters. The oxalate-extractable Fe oxides in the soil can be a proxy of poor drainage on shallow permafrost table and high SOC storage in permafrost soils of black spruce forests.

Figure 1. Tree ring of black spruce