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Total Storage and Landscape Distribution of Soil Carbon in continuous permafrost terrain of the Central Canadian Arctic

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High latitude ecosystems hold large reservoirs of soil organic carbon (SOC). A large part of these C reservoirs have accumulated during the Holocene and are presently stored in permafrost soils and peat deposits. This study assesses total storage and landscape distribution patterns of soil carbon in the continuous permafrost terrain of the central Canadian Arctic. SOC storage in different geomorphic settings and vegetation types is discussed in the context of Holocene landscape development. The landscape allocation of soil C is assessed using a transect-based soil sampling program carried out in the summer of 2006 in continuous permafrost terrain at the shore of Lake Tulemalu, northern Kazan Basin (62° 55´ N, 99° 10´ W). The arctic landscape displays variation on many different spatial scales, and different methods for calculating landscape C pools demand varying approaches to sampling. We compare two upscaling methods: transect upscaling based on field transect inventories and landscape upscaling using a satellite land cover classification (LCC) as spatial proxy.

Deglaciation in this area occurred between 8000-7000 14Cy BP. Present vegetation is treeless, low arctic tundra. Soils were sampled along three 1 km transects, chosen to represent main land cover types and geomorphology. Pedons were collected equidistantly every 100 m (33 sites). Sampling includes upland soils (to 1m depth) and peat deposits (to mineral contact). At all non-peatland sites, three additional samples of the top organic layer were collected. Samples from all sites were analyzed in 10 cm depth increments for bulk density and loss on ignition (LOI at 550° C and 950° C) to determine organic and inorganic C content. A subset of samples (n= 114) were tested in an elemental analyzer to accurately determine C and N content. For remaining samples a LOESS regression model was constructed to translate LOI to C % content. The C:N ratio is used as an indicator of degradation in SOM quality. We use AMS 14C dating (n=17) to determine the ages of cryoturbated soil horizons as well as basal ages of peat deposits and top soil O-horizons.

To enable interpretation and landscape upscaling of soil sampling results, we mapped land cover in the larger surrounding area. A land cover classification (LCC) based on Landsat ETM+ imagery was produced and verified using 85 ground truth points (the 33 transect points sampled for SOC and 52 random points). The LCC separates bare ground, wet, moist and dry shrub tundra, dry lichen tundra as well as fen and bog peatlands. Ground truth points were described in the field for a 5 m radius around the point. The overall accuracy of the LCC is 73 % and the Kappa Index of Agreement is 0.65.
The classification covers some 400 km2 but we focus our landscape upscaling on a
42 km2 intensive study area, delineated to be representative of the sampled sites. For transect upscaling, the soil sampling results are upscaled according to the proportional distribution of land cover types and landscape elements along the inventoried transects. For the landscape upscaling, we use percentage coverage from the LCC.

The depth of the frost table (August 7-13, 2006) was less than one meter in 27 of the 33 investigated sites. Inorganic C content was low in all investigated samples, and almost all C is stored in organic compounds. Peatlands dominate C storage with ca 60 % of all C. Average peat thickness and C storage in raised permafrost bogs is considerably higher than in fens. More than a third of all stored C is perennially frozen beneath the active layer boundary, mainly in bog peat deposits. Radiocarbon dating shows that peat deposits started to accumulate in the area around 5000 14Cy BP, when trees were still present in the area. What is today raised permafrost bog

complexes started to accumulate as fen peatlands, with basal ages ranging from 3490-5220 $\pm$ 90 14Cy BP. Fen peat deposits are generally shallower, with the base of peat formation within the active layer and have basal ages ranging 1015-1405 $\pm$ 60 14Cy BP. Tundra vegetation types cover 60 % of the landscape, together accounting for 40 % of total SOC storage. A quarter of the tundra SOC is stored in top organic horizons, with another quarter found in C rich cryoturbated horizons of the subsoil. Two cryoturbated tundra soil horizons were 14C dated to 3850$\pm$ 35 and 5690$\pm$ 35 14Cy BP. The mean depth of tundra top organic layers increases gradually along a moisture gradient. The wet shrub tundra stores significantly more C than do moist or dry shrub tundra classes, showing the importance of differentiating within shrub tundra classes in the LCC data used for upscaling.