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Reindeer grazing in subarctic boreal forest – influences on the soil carbon dynamics

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Reindeer (*Rangifer tarandus* L.) are the most important large mammalian herbivores in the northern ecosystems , which have many effects on plant diversity, soil nutrient cycling and soil organic matter decomposition. Changes caused by reindeer in vegetation have indirect effects on physical features of the soil e.g. soil microclimate, root biomass and also on soil C dynamics. Earlier, the role of reindeer grazing in ground vegetation dynamics and in soil carbon (C) dynamics has been mostly investigated in open tundra heaths. The objectives of this study were to examine if and how the reindeer grazing (and the possible temperature changes in soil caused by heavy grazing) is affecting the soil C dynamics (CO_2 efflux from the soil, C storage in soil, microbial biomass in the soil).

In a field experiment in Finnish Lapland, in Värriö Strict Nature Reserve (67˚46' N, 29˚35' E) we have assessed the changes occurring in above- and belowground biomasses, and soil C dynamics (CO_2 efflux, soil C content, soil microbial biomass C) among areas grazed and ungrazed by reindeer. Our study areas are located in the northern boreal subarctic coniferous forest at the zone of the last intact forest landscapes in Fennoscandia, where large areas of relatively undisturbed subarctic Scots pine (*Pinus sylvestris* L.) forests can still be found. The sample plots located in the Värriö Strict Nature Reserve (10 sample plots in total established in year 2013) are situated along the borderline between Finland and Russia, where the ungrazed area was excluded from the reindeer grazing already in 1918, to prevent the Finnish reindeer from going to the Russian side and there are not many reindeer on Russian side of the area. To characterize the stands we have established circular sample plots on areas with a radius of 11.28 m, where different tree characteristics were measured (diameter at 1.3 m, height, height of a tree, crown height, crown diameter, stand age, etc.). On every sample plot, four 0.5 x 0.5 m ground vegetation squares were established for species composition and recovery measurements. The squares were photographed for ground vegetation coverage analyses and definition of species composition. Ground vegetation biomass was determined from 4 sample squares (0.2 x 0.2 m) located systematically inside the circular sample plots (close to the ground vegetation squares).

For soil C content measurements 5 soil cores (150 mm in length and 50 mm in diameter) were taken from every sample plot in Värriö and in Sodankylä. The soil cores were divided according to the morphological soil horizons; to litter and organic layer (F-horizon) and humus layer (O-horizon). The layers in mineral soil were divided to eluvial (A-horizon) and illuvial (B-horizon), and sieved. All roots were separated for root biomass calculations. The soil C content was measured with an elemental analyser (varioMAX CN elemental analyser, Elementar Analysensysteme GmbH, Germany). The soil respiration rates were measured only in Värriö study areas. In order to determine the CO_2 efflux from soil to atmosphere, manual chamber measurements with a diffusion type CO_2 probe (GMP343), were performed on 6 collars at each sample plot from June till September (five times per collar) at measuring intervals of two weeks. Soil microbial biomass was measured from five soil samples (soil from lower humus layer) per sample plot in Värriö. To determine the soil microbial C biomass (C_{mic}) and soil microbial N biomass (N_{mic}) chloroform fumigation direct extraction method was used.

The average soil temperatures during the growing season (from June till September) were similar in all sample plots in Värriö, ranging from 10.9 to 11.5 ˚C. There were also no differences between daily average temperatures or soil moisture between grazed and ungrazed areas. There was no statistically significant effect of reindeer grazing on soil C content, although it was mainly higher in grazed area compared to the ungrazed area. Also there was no significant differences in the soil CO_2 efflux between the grazed and ungrazed area. This means that although the soil CO_2 efflux was mostly lower in the ungrazed area, reindeer herding had no significant influence on the soil CO_2 efflux. The CO_2 effluxes were lowest in June. In July and August, the CO_2 effluxes were more than two times higher compared to June.

The microbial biomass C (C_{mic}) measured from humus horizon was lower in the grazed areas compared to the ungrazed areas, but the difference was not statistically significant. However, the microbial biomass N (N_{mic}) was significantly lower ($p > 0.05$) in the grazed areas compared to the ungrazed areas.

We found also that grazing decreased significantly the biomass and cover of lichens in the coniferous forests. In Sodankylä the biomass of lichens was decreased around 74% due to grazing. In Värriö the decrease was even bigger, there the amount of lichen biomass was decreased more than 90% due to reindeer grazing. Ttal above ground biomass was higher in the area where no reindeer grazing had occurred. Moreover, the tree biomass was higher in the area with no grazing and tree regeneration was heavily affected by grazing, as we had much less tree regeneration in the grazed areas compared to the ungrazed areas.