Herbivores influence nutrient cycling and plant nutrient uptake:
Insights from tundra ecosystems

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Abstract
Reindeer appear to have strong positive effects on plant productivity and nutrient cycling in strongly nutrient-limited ecosystems. While the direct effects of grazing on vegetation composition have been intensively studied, much less is known about the indirect effect of grazing on plant-soil interactions. This thesis investigated the indirect effects of ungulate grazing on arctic plant communities via soil nutrient availability and plant nutrient uptake.

At high density, the deposition of dung alone increased plant productivity both in nutrient rich and nutrient poor tundra habitats without causing major changes in soil possesses. Plant community responses to dung addition was slow, with a delay of at least some years. By contrast, a \(^{15}\)N-urea tracer study revealed that nutrients from reindeer urine could be rapidly incorporated into arctic plant tissues. Soil and microbial N pools only sequestered small proportions of the tracer. This thesis therefore suggests a strong effect of dung and urine on plant productivity by directly providing nutrient-rich resources, rather than by stimulating soil microbial activities, N mineralization and ultimately increasing soil nutrient availability. Further, defoliation alone did not induce compensatory growth, but resulted in plants with higher nutrient contents. This grazing-induced increase in plant quality could drive the high N cycling in arctic secondary grasslands by providing litter of a better quality to the belowground system and thus increase organic matter decomposition and enhance soil nutrient availability. Finally, a \(^{15}\)N natural abundance study revealed that intense reindeer grazing influences how plants are taking up their nutrients and thus decreased plant N partitioning among coexisting plant species.

Taken together these results demonstrate the central role of dung and urine and grazing-induced changes in plant quality for plant productivity. Soil nutrient concentrations alone do not reveal nutrient availability for plants since reindeer have a strong influence on how plants are taking up their nutrients. This thesis highlights that both direct and indirect effects of reindeer grazing are strong determinants of tundra ecosystem functioning. Therefore, their complex influence on the aboveground and belowground linkages should be integrated in future work on tundra ecosystem N dynamic.

Keywords
Reindeer grazing, large herbivores, nutrient cycling, plant nutrient uptake, soil nutrient availability, arctic plant ecology, soil microbial communities, \(^{15}\)N stable isotopes, plant-soil interactions, plant quality, dung and urine.