Grazing in Arctic peatlands—an unknown agent in the global carbon budget

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Abstract
Previous studies have offered strong evidence that grazers alter the vegetation composition and ecosystem carbon (C) balance in ecosystems. In Arctic peatlands, however, the role of grazing has remained largely uninvestigated. Falk et al. (2015 Environ. Res. Lett. 10 045001) showed that grazing by muskoxen in a high Arctic mire significantly affected both the vegetation and release of greenhouse gases. This finding highlights the potential of grazers to alter ecosystem processes in Arctic peatlands and, thus, to act as a major player in the global C budget.

Ecologists have long recognized that, in addition to their substantial effects on vegetation, grazers alter the microbially mediated processes of soil carbon (C) and nutrient cycling (Wardle et al. 2004). Recent studies have shown that, through their effect on vegetation and soil processes, grazers may substantially influence the C balance of the Arctic ecosystems as well as the response of the ecosystem to global warming (Sjögersten et al. 2008, Cahoon et al. 2012, Väisänen et al. 2014). These findings have prompted the recognition that grazers need to be considered if the consequences of climate change are to be predicted satisfactorily (e.g., Schmitz et al. 2014). Grazing is an important component of the functioning of Arctic ecosystems. For centuries, large areas of the Eurasian Arctic have been intensively used for the husbandry of semi-domesticated reindeer (Forbes and Kumpula 2009), and even sparse populations of wild caribou exert a significant effect on Arctic vegetation in North America (Zamin and Grogan 2013).

Falk et al. (2015) showed that grazing by muskoxen, one of the keystone grazers in the Arctic, influenced vegetation and greenhouse gas emissions from an Arctic mire. The exclusion of muskoxen for four years produced a thicker moss layer, decreased vascular plant abundance, a decreased net CO2 sink, and lower CH4 release from the mire. This experiment showed for the first time that grazers may influence greenhouse gas emissions from Arctic peatlands. This finding has great significance because Arctic peatlands (e.g., mires) constitute a particularly important component of the global C budget. As a result of the incomplete microbial degradation of organic matter under moist, anoxic and cold conditions during several millennia, Northern peatlands sequester approximately 500 gigatons of C (Yu 2012), representing 16% of Earth’s estimated soil C reservoirs. By this means, even a modest effect of grazing on greenhouse gas emissions from Arctic peatlands could be important for global C cycling. It is particularly significant that the projected rates of future temperature increase in the Arctic are highly likely to outpace the rates of temperature increase over most of the planet, raising the concern that Arctic peatlands may turn into a net C source in the future and contribute to increasing atmospheric greenhouse gas concentrations (IPCC 2013). All previous studies have emphasized the importance of the water level (i.e., the proportion of peat soil layers with aerated versus waterlogged and anoxic conditions) and the temperature for CO2 and CH4 release. However, the findings by Falk et al. (2015) strongly indicate that biotic interactions are important as well. Further understanding of the interactions among grazing, the dominant vegetation, and Arctic peatland C balance could substantially improve the accuracy of predictions of the responses of greenhouse gas emissions to warming in these systems.

Only a few studies have been conducted on the effects of grazing on Arctic peatland vegetation. Here, we gather this scarce evidence and propose a
A conceptual model suggesting that the pathways of future Arctic peatland C balances could result from competitive interactions among plant functional types (Figure 1). In this model, we list possible impacts of grazing and climate change on the relative abundances of bryophytes, graminoids and shrubs/dwarf shrubs, and we present possible mechanisms whereby an increase in each of the plant functional types may influence the C balance. Falk et al. (2015) found that the exclusion of grazers increased the thickness of the moss layer; this result is consistent with earlier observations from Arctic tundra heaths and dry and wet meadows (van der Wal et al. 2007, Gornall et al. 2009, Sjögersten et al. 2011). A reduction in the moss layer in response to grazing reduces both soil insulation and competition among plants for nutrients and, consequently, may increase the proportion of graminoids in the vegetation (Gornall et al. 2009, Sjögersten et al. 2011). Falk et al. (2015) hypothesize that the shift in relative bryophyte and graminoid abundance is also the reason that grazing decreased ecosystem CH4 release: there is a close correlation between CH4 release and plant primary production, with Eriophorum plants having a particularly important role in methanogenesis (e.g., Falk et al. 2014).

We also suggest that grazers most likely alter greenhouse gas balances in Arctic peatlands by decreasing the abundances of deciduous shrubs and dwarf shrubs (Figure 1). Evidence from Arctic and subarctic peatlands suggests that grazers reduce the abundance of willows (Salix sp.) and dwarf birch (Betula nana L.) in many systems (Oksanen and Virtanen 1995, Kumpula et al. 2004, Kittel et al. 2009). In dwarf shrub-dominated tundra heaths on aerated soils, grazing has been shown to counteract the warming-induced increase in shrub abundance (Olofsson et al. 2009) and to alter C-cycle feedback to warming (Cahoon et al. 2012, Väisänen et al. 2014). Accordingly, a similar feedback mechanism might occur in peatlands. In a temperate peatland, a grazer-induced shift from mosses and ericoid shrubs to graminoids increased the net ecosystem C sink, simultaneously increasing CH4 emissions (Ward et al. 2007). In Arctic permafrost systems, the experimental removal of shrubs led to increased CH4 emissions because decreased shading by shrubs led to a collapse of permafrost that, in turn, produced more waterlogged—and hence, anoxic—conditions in the soil (Nauta et al. 2015). These various studies highlight the complexity and variability of the possible pathways by which grazer-induced changes in plant functional types in peatlands could alter ecosystem CO2 and CH4 balances and their response to climate change (Figure 1).

Due to the global significance of Arctic wetlands as C stocks, we suggest that the work by Falk et al. (2015) should inspire more experiments investigating grazer-induced effects on greenhouse gas emissions in peatlands across the Arctic. Given the slow recovery of shrub vegetation from browsing, these experiments should include both experimental short-term grazer exclusion and comparisons of areas that have experienced differing grazing intensities over decadal timescales (sensu Väisänen et al. 2014). From what we have learned about the role of grazing in Arctic tundra heaths and meadows, we might expect these effects to be strong and highly variable for different vegetation types and grazing intensities. Determining the role of grazing in Arctic peatland C sink and source dynamics is thus, most likely, a complex task.

Figure 1. A conceptual model describing possible pathways by which grazing and climate change may influence Arctic peatland C storage, CO2 balance, and CH4 release.
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