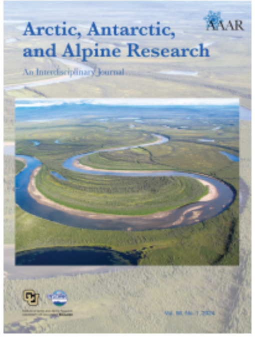

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Can animal grazing help to reduce permafrost thaw?

Torben Windirsch, Bruce C. Forbes & Jens Strauss

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ARCTIC ANSWERS

Can animal grazing help to reduce permafrost thaw?

THE ISSUE. Permafrost soils—perennially frozen ground and overlying thin seasonally unfrozen layer soils that contain a large portion of the global soil carbon—were long known as a protective feature for decomposable organic material. With ongoing climate warming, these deposits are thawing rapidly, creating both local and global challenges. Local ground collapse puts infrastructure at risk, affects Arctic livelihoods, and changes terrestrial and aquatic habitat characteristics, and carbon emissions from thawing permafrost contribute to intensifying global warming. As large herbivorous animals were identified around the globe to have direct and indirect impacts on ground and soil conditions, calls arose for the implementation of herbivory management strategies utilizing animal impacts to possibly help stabilizing permafrost (Figure 1)[1]. Because Arctic peoples' livelihoods depend on the state of the Arctic environment, their views must be included in every action taken, especially since traditional knowledge often exceeds scientific knowledge regarding specific areas.

WHY IT MATTERS. The widespread **loss of permafrost** because of climate warming poses threats to the livelihoods of the Arctic, because unstable ground conditions damage housing, water sources, travel routes, pipelines, and more. Further, thawing permafrost exposes once-frozen organic material to microbial degradation, and hence **greenhouse gas emissions** from Arctic ground are increasing. This fuels climate warming by contributing to rising atmospheric carbon levels. Thawing permafrost results in rather wet unfrozen soils, so microbial activity will often be under anaerobic conditions, leading to the formation of methane, which is a much more potent greenhouse gas than carbon dioxide. Though ground subsidence also affects Arctic vegetation and animals, these animals are hypothesized to exert positive effects onto stabilizing the permafrost tundra ecosystem, posing as **ecosystem engineers**. Increasing livestock of (semi-)domestic or population size of wild large herbivores could help to reduce ground insulation, leading to **colder ground conditions** and slowing down permafrost thaw, while at the same time transforming vegetation (Figure 2) toward a **productive grassland** ecosystem. In areas with a history of animal herding, increasing herd sizes might be the most feasible option[2,3].

STATE OF KNOWLEDGE. Long-term experiments, assessment of traditional knowledge, and modeling have shown that high densities of large herbivores like reindeer, bison, or horses lead to reduced thaw in permafrost via various pathways[4]. These findings refer to modern open tundra landscapes, because extant Arctic animals are not capable of changing main vegetation structures in forest landscapes. During the Ice Age, however, mammoths were able to push trees over. However, the much higher animal density in the northern regions during the Pleistocene prevented trees from growing tall in most places, creating a grass-dominated landscape. This ecosystem allowed for intensive cooling of the ground during the long winter periods, because the grassy vegetation did not catch snow, and numerous animals trampling down the snow led to less insulated ground. The soil froze deep, maintaining and creating permafrost, topped by an "active layer" that would thaw during summer and refreeze in winter. Nowadays, we see a deepening of this active layer across the permafrost region and incomplete refreezing of it during winter. This is also due to increasing shrubification, especially in the absence of herbivory, that promotes earlier snowmelt by affecting the albedo[5]. In unfrozen conditions, microorganisms can remain active throughout the year, breaking down organic material contained in the soil, producing and releasing greenhouse gases.

By reintroducing high animal densities to tundra landscapes, the soil cooling effect arising from animal trampling in winter can be artificially promoted, helping to stabilize permafrost conditions again (Figure 1). However, the high animal densities that are required for this are not occurring naturally anymore. Hydrology, however, also plays a crucial role in how large herbivores affect Arctic and subarctic ecosystems. High densities of large herbivores in wet lowlands could even accelerate permafrost thaw[6]. Therefore, it is recommended to customize efforts to actively use the stabilizing effects of animals according to the specific location and the site-specific needs of its land users, especially those who have historically farmed or currently farm animals like reindeer. Nevertheless, in Alaska and Canada, herds of caribou are wild migratory animals, some of which have been in decline in recent decades. For example, the Western Alaska caribou herd is only a fraction of its former size, with animal numbers dropping by almost 70 percent since 2003. People suspect various influencing factors, including pests, warming, shifting links in the food chain, more frequent winter rain–on-snow events, changes in snowfall, and increased fragmentation of the landscape. These are some of the factors of environmental

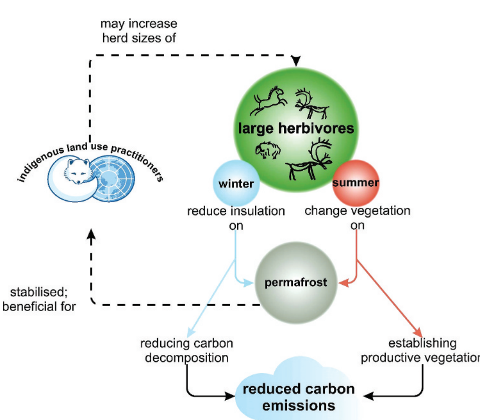

Figure 1. Relationships between the potential impact of herbivory on the northern environment and their socioeconomic effects. Arctic Council logo: Arctic Council.

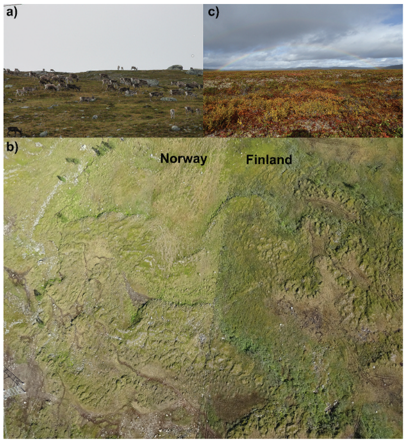

Figure 2. (a) grassy tundra under reindeer grazing impact. Photo by Sari Stark. (b) Finnish–Norwegian border; reindeer allowed on the Norwegian side (left) and mostly excluded on the Finnish side (right). Drone image courtesy Matthias Siewert. (c) Shrubby tundra in the absence of herbivores. Photo by Fabian Seemann.

change that make it harder for large cold environment herbivores to thrive in large numbers and that will make it even harder to increase herd sizes enough to influence permafrost soils.

Because the effects of land management practice of increasing herbivore stocks would only show at very high animal densities and over decadal timescales, implementing a utilization scheme of herbivory in cooperation with Arctic animal herders and farmers could represent a feasible local mitigation strategy to reduce the effects of permafrost thaw. Even local applications could benefit both local human populations by providing subsistence and income as well as somewhat reducing permafrost–carbon feedbacks on the global climate. In areas without a herding history, animal numbers might still be increased, offering better options for hunting and subsistence livelihoods. However, there are differences between the impact of different animal species, grazing seasonality, environmental state, and soil and vegetation types. Due to the high animal densities required and variable local conditions, approaches must be local and can only complement other strategies to mitigate permafrost emissions of greenhouse gases.

WHERE THE RESEARCH IS HEADED. The potential direct and indirect impacts of animals on permafrost have been discussed and are a focus of ongoing research, but there is also a need to assess the carbon fluxes within the whole ecosystem, as well as the economic pathways of hunting, selling meat, etc. This opens the floor for the introduction of other herbivore species such as bison, horses, cattle, musk oxen, etc., that might exert even stronger positive impacts on thawing permafrost (Figure 1).

From the natural scientist perspective, this calls for large-scale experimental sites with continuous monitoring of all critical environmental parameters in a close-to-natural state. Though existing computer models are implementing increasing numbers of parameters, in situ measurements are necessary to provide ground truth data to be fed into those models. We further need to assess the maximum animal numbers that can be carried by a specific landscape as well as herded by land users and identify potential conflicts with existing forms of land use. Northern ecosystems and landscapes vary, and there are no one-size-fits-all solutions. Intensifying herbivory through rewilding and herding could help slow permafrost thaw and mitigate climate change.

From a socioeconomic point of view, we need to address the following questions: How would subsistence use change? Is there a good market for this meat or other products? How do local economies best profit? For successful development of a climate-effective and socioeconomically integrated herding strategy, it is vital to apply a co-creative and community-based approach, teaming with indigenous rights-holders, scientists with various backgrounds and fields, politicians, and all other land users.

Disclosure statement

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Supplementary material

Supplemental data for this article can be accessed online at https://doi.org/10.1080/15230430.2024.2379717.

Contact Authors for More Information:

Torben Windirsch
Research Institute for Sustainability Helmholtz Centre Potsdam, Germany
Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
torben.windirsch@rifs-potsdam.de

Bruce C. Forbes
University of Lapland, Finland
bruce.forbes@ulapland.fi

Jens Strauss
Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
jens.strauss@awi.de