BOREAL AND ARCTIC LANDS: DIGGING DEEPER Shirley, cloudyclimate.org, May 8, 2025

Boreas, the Greek god of the North, gives his name to the northern boreal lands, mapped between 50° and 70°N latitude, that include forest, interspersed peatlands, and treeless tundra. The largest boreal forest is the Russian Taiga, extending into Scandinavia. The term 'taiga' (not capitalized) can also mean boreal forest or just the northern fringe bordering tundra. The second largest North American boreal forest spans 1.5 billion acres (~600 billion hectares) and may be the largest intact woods in the world.[1]

One third of land on Earth is covered by forests, of which 45% are tropical, 27% boreal, 16% temperate, and 11% subtropical.[2] Boreal forests store almost twice as much carbon as tropical forests, mostly in the soil, where decay is slowed by cold and/or water saturation. About 85% of boreal carbon is underground, compared to 50% for tropical forests.[3] Most land plants have symbiotic mycorrhizal fungi associated with their roots, that help plants obtain nutrients from the soil. The fungi play a role in carbon storage, in part by using it to build a mycelial network that also stabilizes soil. The type of mycorrhiza that partners with boreal trees gets a bigger allocation of carbon than does the other major mycorrhizal fungus type.[4]

Peatlands, a kind of wetland, are found on every continent, and hidden peatlands are still being discovered. Fens and bogs have a reputation for being spooky, smelly, and unhealthy (like the moors in the Hound of the Baskervilles) but are undervalued. They store and filter water and are home to many birds, animals, and plants.[5] Sedges and mosses absorb CO2 photosynthetically, but plant litter is prevented from fully decomposing by the waterlogged conditions, making peat instead of returning CO2 to the atmosphere. Peatlands are a net carbon sink, even though they emit methane, and store more carbon than in all of the world's forests combined while covering only 3-4% of the Earth's land surface.[6]

Dried peat burns well and was long used for household heating. Wildfires that burn peat are smoky, difficult to put out, and can smolder and reignite, zombie-like.[7] About 12% of peatlands globally have been drained to make room for crops, forest, or livestock. Drained peatlands emit greenhouse gases that are 4% of annual global human-induced emissions.[6] Rewetting drained peatlands will stop CO2 emissions and reduce climate warming despite restarting methane emissions.[8]

Decay of plant matter is slow in the cold and slower yet in permafrost, ground that remains frozen for at least two consecutive years. Carbon can remain sequestered here for thousands of years. Permafrost in the Boreal-Arctic zone underlies boreal forest (below an active soil layer) and tundra; permafrost can also be alpine or underwater. The Arctic, however, is warming 2-4 times faster than the rest of the globe,[9] and permafrost is thawing. Already the landscape is changing. As ice melts and ground collapses, uneven thermokarst landscapes emerge.[10] Land slumps, lakes can appear and disappear, and roads and houses become unstable.[11] Gradual thawing releases CO2 and methane as the once-frozen peat decomposes. But in around 20% of frozen lands, there are large quantities of ice in the ground or unstable slopes that increase the chances of abrupt thawing and gushes of greenhouse gases from deeper layers. For example, Yedoma is a kind of thick permafrost that may be 90% ice, and it is extremely vulnerable to this.

Permafrost thaw has been called a 'sleeping giant' or 'Pandora's freezer' or a potential time bomb. Is permafrost stable or is this a possible tipping point?[12] Models weigh increased CO2 uptake by expanding vegetation (greening) against carbon additions to the atmosphere from previously frozen peat soils and wildfires.[13] The data shows the permafrost region shifting from carbon sink to carbon source, when fire emissions are factored in.[14]

It's hard enough using tree cover to measure forest carbon. Below ground is harder. Digging deeper, I've learned that boreal forests store more carbon and more carbon in soil than tropical forests, peatlands store more carbon than forest lands, and permafrost contains a third of global soil carbon. What is the lesson from trees, fungal networks, soils, peatlands, and permafrost? Keep carbon in the ground.

REFERENCES

[1] **Evergreen. Saving big forests to save the planet.** JW Reid & TE Lovejoy, 2022. This book makes the case for keeping forest unfragmented in the five remaining megaforests – the New Guinea, Congo, and Amazon tropical forests and the North American boreal zone and Taiga, with visits to each and maps.

[2] Global forest resources assessment 2020, key findings. Food and Agriculture Organization of the United Nations (FAO) (https://openknowledge.fao.org/server/api/core/bitstreams/9f24d451-2e56-4ae2-8a4a-1bc511f5e60e/content)

[3] Soil Fungal Community and Potential Function in Different Forest Ecosystems. X Li et al, Jun 2022 (https://doi.org/10.3390/d14070520)

[4] Mycorrhizal mycelium as a global carbon pool. H-J Hawkins et al, Jun 2023 (https://doi.org/10.1016/j.cub.2023.02.027). Arbuscular mycorrhizal fungi are associated with the roots of ~70% of land plant species. Only 2% of species depend on Ectomycorrhizal fungi but these cover 25% of global vegetation, especially in taiga/boreal regions; plants allocate more carbon to Ectomycorrhizas.

[5] **Fen, Bog & Swamp**. Annie Proulx, 2022. Enjoyable reflections on English fens, bog bodies, sphagnum moss, the swampier United States of the past, etc., in history and art and the present.

[6] Global peatlands assessment: the state of the world's peatlands, UN environment programme, 2022 (https://www.unep.org/resources/global-peatlands-assessment-2022). Peatlands cover 500,000 hectares globally and contain ~600bn tonnes (GtC) of carbon. 18% of peatlands are located in protected areas.

[7] 'Zombie fires' in the Arctic. P Louchouarn, Jul 2023 (https://theconversation.com/zombie-fires-in-the-arctic-canadas-extreme-wildfire-season-offers-a-glimpse-of-new-risks-in-a-warmer-drier-future-209666)

[8] Questions & Answers: bringing clarity on peatland rewetting and restoration. Greifswald Mire Centre and Wetlands International, May 2023 (https://globalpeatlands.org/sites/default/files/2023-07/QA-peatland-rewetting_fin.pdf). Peat takes millennia to generate, but restoration can start to regrow plants.

[9] The Arctic has warmed nearly four times faster than the globe since 1979. M Rantanen et al, Aug 2022 (https://doi.org/10.1038/s43247-022-00498-3)

[10] Thawing permafrost is roiling the Arctic landscape, driven by a hidden world of changes beneath the surface as the climate warms. MJ Lara, Apr 2022 (https://theconversation.com/thawing-permafrost-is-roiling-the-arctic-landscape-driven-by-a-hidden-world-of-changes-beneath-the-surface-as-the-climate-warms-174157). Photos show landscape changes including a pingo and polygons from ice wedge melt.

[11] Permafrost collapse is accelerating carbon release. MR Turetsky, May 2019 (https://media.nature.com/original/magazine-assets/d41586-019-01313-4/d41586-019-01313-4.pdf)

[12] Past permafrost dynamics can inform future permafrost carbon-climate feedbacks. MC Jones et al, Jul 2023 (https://doi.org/10.1038/s43247-023-00886-3). Includes subsea and sub-permafrost methane.

[13] Ecological response to permafrost thaw and consequences for local and global ecosystem services. EAG Schuur & MC Mack, Nov 2018 (https://doi.org/10.1146/annurev-ecolsys-121415-032349). Permafrost contains a third of global soil carbon measured to 3-meters; likely more, since permafrost can be hundreds of meters deep. Also: Permafrost and climate change: carbon cycle feedbacks from the warming arctic. EAG Schuur et al, Oct 2022 (https://doi.org/10.1146/annurev-environ-012220-011847)

[14] Wildfires offset the increasing but spatially heterogeneous Arctic-Boreal CO2 uptake. A-M Virkkala et al, Jan 2025 (http://dx.doi.org/10.1038/s41558-024-02234-5)

In case you were wondering... Permafrost as a potential pathogen reservoir. R Wu, et al, Apr 2022 (https://doi.org/10.1016/j.oneear.2022.03.010). In 2016, a person and thousands of reindeer died from anthrax; between 1897 and 1925, 1.5 million deer died. The risks to human health are generally low, but many microorganisms and viruses residing in permafrost have not yet been studied.