GreenLearning
Backgrounder

Thawing Tundra

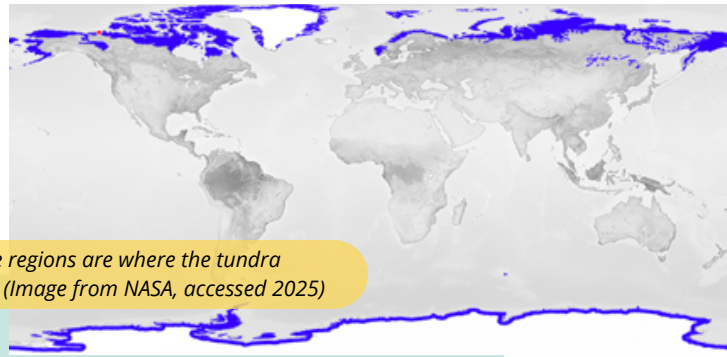
From Carbon Sink to Carbon Source

Permafrost, found in the tundra, is a layer of soil that is usually "**perma**nently" frozen. What happens when permafrost is not so "perma" anymore? As global temperatures rise, the Arctic is experiencing warmer temperatures leading to the thawing of permafrost. What impact does this thaw have on climate change?

In this backgrounder, learners will learn about the tundra biome and permafrost, and find out more about the consequences of a thawing tundra.

The Tundra

The tundra is the coldest of the biomes and is mainly found in the Earth's polar and subpolar regions or high mountains. The tundra in Canada extends across much of the mainland in northern territories and provinces, including Yukon, Northwest Territories, Nunavut, and parts of northern Quebec and Labrador. Tundra also covers the Canadian Arctic Archipelago, which mainly consists of numerous islands in the Arctic Ocean, including Baffin Island, Victoria Island, and the Queen Elizabeth Islands.



This map's blue regions are where the tundra biome is found (Image from NASA, accessed 2025)

Biomes

A biome is an area on the planet that is classified according to the living organisms (plants and animals) that live in that region. Six broad classifications of biomes include ***tundra***, ***desert***, ***grassland***, ***forest***, ***freshwater*** and ***marine***.

Biome vs Ecosystem: What's the difference?

- **An ecosystem is about the unique network of things interacting** under certain conditions. As an analogy, you could think of a grade two class as an ecosystem.
- **A biome is about identifying the type of area based on what lives there**. To stick with our analogy, a biome is like determining that a building you're looking at is a school (because you noticed a bunch of students and teachers in the building).

If you think about our analogy, there are probably a few different grades and types of classrooms in a school! You can also expect a specific biome ("school") to have certain ecosystems ("classes") inside them.

The tundra has a cold and harsh climate, but there is plenty of life! Around 150,000 people live in Canada's Arctic region, and more than half of these people are Indigenous. Lichens and mosses grow in the tundra, along with shrubs, sedges and grasses. However, very few trees can grow at all, due to the permafrost and very short growing season. A variety of animal species can be found in the Canadian tundra, including Arctic foxes, polar bears, gray wolves, caribou, snow geese, and musk oxen. These animals are well adapted to the extreme conditions of the tundra.

The arctic tundra experiences long, cold winters and short, cool summers. Take the weather conditions at Aklavik, NT as an example; its average monthly temperatures can range from around -30°C in January to 14°C in July. The tundra also receives low amounts of precipitation, 150 to 250 millimeters of rain per year, making the tundra similar to a desert (NASA, 2025).

The word tundra comes from the Finnish word tunturia. Tunturia means "treeless plain".

Permafrost

The soil in a typical tundra is usually comprised of two layers, the active layer and the permafrost layer. The active layer normally thaws during the short summer months (50 to 60 days) and freezes again for the rest of the year (NOAA, 2019). This layer of soil is usually not very deep and in the cold regions, the ground rarely thaws - the active layer could be just 4 to 6 inches (about 10 to 15 centimeters) thick!

Below the active layer is the permafrost layer. Permafrost is a defining characteristic of the tundra. It is made of soil, rocks and sand that are held together by ice. The soil and ice in permafrost stay frozen (below 0 °C) all year long. Therefore, only low growing plants with shallow root systems like grasses, mosses, lichens, and small shrubs can grow in the tundra. The frozen ground also inhibits water drainage, resulting in the formation of ponds, lakes, and marshes. These wetland areas provide important habitat for various species and support high biodiversity in the tundra ecosystem.

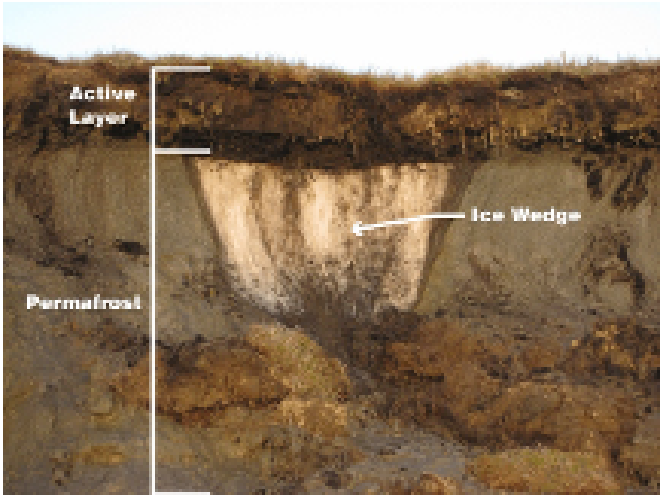


Photo credit: Benjamin Jones, USGS. Public domain (modified)

Tundra - A Carbon Sink?

The Arctic tundra used to be considered a carbon sink, meaning that it absorbed more carbon dioxide from the atmosphere than it released back into it during the summer growing season. This carbon uptake occurs through the process of photosynthesis, where plants use sunlight, water, and carbon dioxide to produce organic matter, including plant biomass. Additionally, as plant materials decompose, the organic matter is added to the soil. This organic matter contributes to the buildup of carbon in the surface layer of soil. In colder climates, decomposition rates are relatively slow, allowing organic matter to remain in the soil.

There is a LOT of carbon stored in the northern permafrost region; total organic carbon stored in this region is estimated to be 1,460 -1,600 billion metric tons (Arctic Report Card, 2019), *which is about twice as much as currently contained in the atmosphere!*

However, with an increase in temperature, things are changing and the Arctic tundra is no longer a carbon sink.

The Yedoma permafrost is well-known for its high organic carbon content, making it a significant reservoir of carbon in the Yedoma regions which include northern Yakutia, Alaska and Yukon. Yedoma deposits originated during the last Ice Age (roughly 20,000 years ago) when these regions were not covered by ice. During that time, fine silts known as loess were deposited by wind action and buried vast amounts of organic materials, such as plant remains and animal remains, within the soil. This organic carbon has been preserved for thousands of years due to the cold temperatures and frozen conditions of the permafrost.

Tundra - A Carbon Source!

"The land areas of the Arctic have been a carbon sink for thousands of years, meaning there has been a net removal of carbon dioxide from the atmosphere by plants, with long-term storage in the soil and permafrost.

However, increasing surface air temperatures are causing permafrost to warm and thaw, allowing stored carbon dioxide and methane to be released into the atmosphere. Wildfires and other disturbances are adding pulse releases of carbon dioxide and methane. These changes together have shifted the Arctic tundra from a net carbon sink into a source."

- Haley Thiem, NOAA, December 2024

The Arctic region has experienced rapid warming compared to the rest of the world. The average air temperature in the Arctic has increased by over 3 degrees Celsius, which is three times the global average warming rate. As temperatures increase, changes happen in the tundra that lead to the release of stored carbon into the atmosphere. This release of carbon is outpacing any storing occurring, which is why we can no longer call the Arctic tundra a carbon sink.

As things warm up, what's happening in the tundra?

Thermokarst Lakes

Accelerated warming is contributing to the thawing of permafrost. (McGee and Gribkoff, 2022). As the air temperature rises, the surface permafrost will thaw. As the ice within the permafrost melts, it creates voids. These voids can cause the land surface to sink and form depressions that fill with water from the melting ice, creating thermokarst lakes.

The water in the lakes absorbs and retains heat from the sun, leading to further warming of the surrounding permafrost and the underlying layers of soil. This accelerated thawing can cause several meters of soil to become less stable in just a few weeks, resulting in land subsidence. As the permafrost thaws and the ground becomes less stable, the added weight and pressure from the water in the lakes can destabilize slopes, leading to increased erosion and landslides.

The polygon shapes in the snow indicate that the permafrost underneath is melting.
Photo credit: NASA/JPL-Caltech/Charles Miller

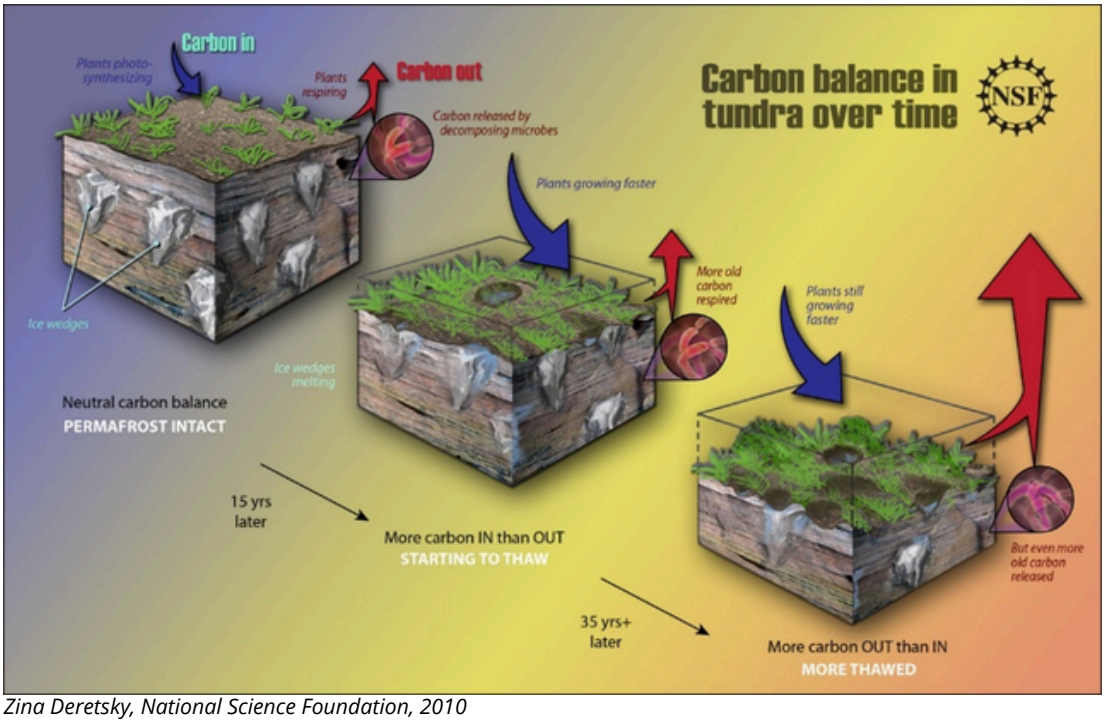
Thermokarst lakes.
Photo credit: Miriam Jones, U.S. Geological Survey

Thawing permafrost falling into the ocean.
Photo credit: Christopher Arp, U.S. Geological Survey

Increased Microbial Activity

When permafrost thaws, it creates favorable conditions for microbial activity and decomposition processes. As the frozen organic matter becomes exposed to warmer temperatures, microbes break down the organic carbon, consuming it as a source of energy and releasing carbon dioxide and methane as byproducts. These greenhouse gases can then enter the atmosphere, contributing to the greenhouse effect and potentially exacerbating climate change.

As permafrost thaws in the tundra, initially there is increased plant growth and a net carbon sink effect. However, as thawing progresses, the carbon released from decomposing organic matter surpasses plant uptake, resulting in a net release of carbon into the atmosphere.



Zina Deretsky, National Science Foundation, 2010

Eventually, if global warming is not controlled, substantial amount of organic carbon stored in the permafrost will be released to the atmosphere within decades, making tundra one of the largest carbon sources to the global warming effect.

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