How alpine ecosystems are responding to climate change: It all comes down to the soil

September 16 2019

Which alpine plants will benefit from climate change depends greatly on the soil, which provides them with water and nutrients. The Bavarian gentian has disappeared from many Swiss mountain peaks. Credit: F. Hagedorn, WSL

Alpine flora is changing rapidly as a result of climate change. Soils are a vital but largely unexplored factor in this process. They also store the

biggest amounts of CO_2. However, how alpine soils will change in a warmer climate is largely unknown, according to researchers at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), writing in the journal *Science*.

In mountainous areas, hidden from view beneath the soil surface, processes of vital importance to the climate and ecosystem are taking place. Over 10,000 different types of microorganisms, such as fungi and bacteria, live in alpine soils. In the alpine zone, 90 percent of carbon is located under the ground. Soils also play a crucial—and largely unknown—role in the changes to alpine vegetation caused by climate change.

The climate is warming particularly fast at high elevations, meaning that alpine plants are expanding their range upwards. If temperatures rise by the predicted 2 to 4 degrees Celsius over the course of this century, the growth limit for plants could rise by between 300 and 600 meters. However, plants rely on soil to store nutrients and water. Soil formation "lags a long way behind the warming climate," according to WSL soil ecologist Frank Hagedorn. Observations along melting glaciers reveal that it takes centuries, if not millennia, for new soil to form from rock.

This will favor the spread of plants that can survive with little soil, such as the alpine moon-daisy and alpine bluegrass, whereas species that prefer well-developed soils rich in humus will be left behind. As a result, the composition of communities will change in unpredictable ways, both above and below ground.

"Soils are the terra incognita of the alpine world," says Hagedorn. They are home to the greatest biodiversity of all high-mountain habitats but only a fraction of the functions performed by these organisms are known. So it is fitting that the review article in which Hagedorn and his colleagues summarize the interdependencies of plants and soil in

warming mountain environments should appear in a special issue of *Science* marking the 250th anniversary of the birth of naturalist Alexander von Humboldt. Humboldt not only described the vegetation zones at different altitudes but also compared these zones in different mountain ranges worldwide.

Carbon store or carbon source?

The way soils change as the mountains warm up also has implications for the climate. Soils contain 90 percent of the carbon in alpine ecosystems, carbon which would otherwise be fueling climate change in the form of CO_2. However, this carbon storage differs from place to place. Close to the vegetation limit, more plants will grow as the climate becomes more favorable, which will result in more carbon being stored in the soil. At the same time, though, more CO_2 will be released as the permafrost thaws and forest starts to colonize higher elevations. After all, current evidence suggests that soils will still lose CO_2 even if new forest becomes established above the current treeline.

Indeed, the data indicate that, overall, CO_2 losses from the soil will outweigh any additional carbon storage, Hagedorn explains. He carried out an experiment at Davos in which cables were used to heat the soil for six years. This led to losses of CO_2 stored in the soil and changed the soil's microbial diversity, which increased the availability of nutrients for plants and so promoted their growth.

Monitoring mountain soils intensively

Despite the vital importance of these underground processes for the climate and ecosystem, little research has been done into the alpine soil that covers at least one third of Switzerland's land area. Hagedorn bemoans the fact that only one single soil profile above the forest line

has been recorded by the Swiss National Soil Monitoring Network (NABO), and we know next to nothing about the quantities of CO_2 stored in alpine permafrost anywhere in the Alps. The authors of the article therefore want to see soil and the organisms inhabiting it become an integral part of long-term vegetation monitoring programs linked to climate change, such as the GLORIA program, which tracks climate-related changes to biodiversity on around 130 high mountain peaks on six continents.

More information: Frank Hagedorn et al. Above- and belowground linkages shape responses of mountain vegetation to climate change, *Science* (2019). DOI: 10.1126/science.aax4737

Provided by Swiss Federal Institute for Forest, Snow and Landscape Research WSL