In the Le Forbonnet raised bog near Frasne in the Jura mountains of France, open top chambers simulate climate warming on a small scale.
The raised bog that glistens in the sun has neither sirens nor warning lights. Yet it acts as a warning system: an early warning system that indicates how the vast bogs in the northern regions of the planet could be modified by climate change – with an impact on the world’s climate. WSL researchers Alexandre Buttler, a professor at EPFL, and Luca Bragazza, a professor at the University of Ferrara, work on this magnificent early warning system near Frasne in the Jura mountains of France. They don’t look very professorial today: they’re wearing rubber boots and work clothes, and carrying oversized drills and high-tech devices along a small wooden walkway across the bog, where the first plants are beginning to sprout up. The water shimmers among the plants, mainly red and yellow peat mosses. Because it is so soon after the snowmelt Le Forbonnet raised bog is literally full to the brim with water. Buttler’s hand disappears into the squishy soil and pulls out a slimy mass. “The green ones are the living peat moss plants. The yellow section with the strands in it are what’s left from the last two, three years; you can still see stems of the moss plants in it. It’s known as blond or white peat,” he explains.

**Raised bogs store a lot of carbon**

He and Bragazza now pick up the drill. Working together, they screw the 1.5-m-long tubes into the ground. Then they remove the drill. “That was easy – too easy,” says Buttler. And he’s right: the bog soil isn’t ready to reveal its inner secrets yet; the drill core has come out of the drill and is stuck in the ground. “When the ground is soaked, you almost never get a sample out of it,” notes Buttler, and he moves a few meters away to try again – in a somewhat drier area, where the pine forest slowly edges into the bog. This time, it’s more difficult to remove the tube. Using a sort of giant pipe cleaner, Buttler pushes the drill core into a second tube that opens lengthwise. Bragazza opens it. In addition to living peat moss and blond peat, there are also a few centimeters of black peat from the deeper layers. “This is where the atmospheric carbon that the peat mosses pulled from the air decades and centuries ago is stored,” explains Bragazza. “Because there is a lack of oxygen in raised bogs and because peat mosses contain substances that inhibit degradation, the plants are barely decomposed. So the raised bog grows a little more each year.”

This peat accumulation makes raised bogs to act as carbon sinks. Around the world, they store nearly a third of all soil carbon stock, although they only cover 3% of the earth’s surface. The peat layer at Le Forbonnet is about four meters deep. Bragazza compares it to an 8,000-page book that grows by a page each year and records information about the climate and pollutants at the time of formation. Like Buttler, he has been researching the raised bog habitat since he completed his dissertation.

It is a habitat that has become rare in Switzerland. Over the last 200 years, humans have destroyed 95% of raised bogs through drainage and peat extraction. Today, there are only about 1,500 hectares of raised and transitional
bogs; this is about the size of 20 golf courses and is insignificant in global terms. “Because Switzerland is climatologically on the southern distribution boundary of raised bogs, our bogs are particularly good as early warning systems for the consequences of climate change,” says Buttler. “In addition, they are small and therefore susceptible to strong boundary effects.” This means, for example, if the ground is dry enough for trees to grow, a bog that is a couple hundred meters in diameter will quickly become overgrown with trees – or at least the seeds of the trees are present.

**Climate change leads to the destruction of peat**

Things are different in Siberia, where bogs can be dozens of kilometers in diameter. Bragazza warns: “If it gets warmer and drier in the summer, it’s not only the vegetation that will change. More plant material will be decomposed than is produced. The bog will start releasing carbon instead of storing it.” He removes a probe from a cylinder-shaped cover, attaches it to a measuring instrument and lowers the slowly buzzing instrument to the bare ground. He measures the smallest changes in the carbon content of the air at ground level. “This is how we measure soil respiration. And how microorganisms break down the peat.” The microorganisms aren’t very active today. But Bragazza’s research reveals that the peat body in Le Forbonnet is releasing carbon throughout the year – unlike the past few thousand years. His studies in two other bogs show that with the climate warming a larger amount of older carbon is released than had previously long been stored in the ground as peat. The changing climate could therefore lead to a reduction in peat accumulation in many places. However, it is still not clear whether the released carbon dioxide will further heat up the atmosphere as a greenhouse gas because the trees that are now growing there may store the carbon for a few more decades or centuries. So researchers from the University of Orléans plan to set up an eddy covariance flux tower in Le Forbonnet. This complex installation can measure the carbon balance of the entire bog, including the trees.

**Jura – Poland – Siberia**

Together with their French colleagues, Buttler and Bragazza installed a set of open top chambers in Le Forbonnet seven years ago. These hexagonal plexiglass structures leave solar radiation, rain and wind largely unchanged, but they reduce heat emissions during the night thus passively simulating climate warming. The advantage of such experiments is that researchers can compare the manipulated surfaces directly with the unmodified neighboring surfaces. But they also have important disadvantages: the conditions are ultimately artificial, because these “new” conditions have only existed for a relatively short period of time, and only small areas can be influenced – especially in bogs, as they have stringent protections. Bragazza and Buttler therefore rely on a number of different methodological approaches. In the Jura and the Alps, they examine bogs at different altitudes. At low altitudes, it is relatively warm and the amount of precipitation is fairly low. The conditions are therefore similar to those that will probably exist at higher altitudes in a few decades as a result of climate change. The spatial gradient serves as a model for the development over time of bogs under changing climate conditions. The same applies to research areas
in Polish and Siberian bogs, where WSL researchers work with regional partners to investigate whether our bogs, which are characterized by a fairly oceanic climate, react differently to climate warming than bogs in a continental climate. “In Poland we work with a professor who was a postdoc with us in Lausanne,” says Buttler proudly. The Mukhrino bog in Siberia is in an even more continental climate, about 2,600 km or a three-hour flight east of Moscow. Working with French and Russian colleagues, Buttler and Bragazza laid kilometers of cable, built walkways and installed open top chambers themselves; once, a Russian colleague delivered the bog soil samples by train and car to France – a trip that took several days and which his European colleagues only learned about when the Russian appeared at their door with the frozen samples in his luggage. The samples are currently being analyzed.

Even without these analyses, early warning systems like Le Forbonnet have already made one thing clear: climate change is altering – endangering – raised bogs. The WSL researchers now want to understand the precise mechanisms. “The crazy thing is that climate change is triggering processes in bog soil that are increasing the release of carbon,” explains Bragazza. “These processes are
based on the complex interaction among plants, fungi, bacteria and abiotic factors. We need biogeochemical analyses of samples from the field and from experiments in the lab in order to understand these processes in detail.”

**Raised bogs and climate change influence one another**

For example, there is increased growth of plants of the heath family (Ericaceae). Dwarf shrubs reduce the water content of the bog soil. Because they sometimes have long roots, unlike the rootless peat moss, their water supply does not suffer with the warming. In addition, they release substances from the roots that, together with the oxygen extracted from the air, contribute to the decomposition of the peat. And they bring some of their “partners” along with them: mycorrhizal fungi. With their help, they can use nutrients such as nitrogen more efficiently, grow faster and outcompete weaker peat mosses. This increases their influence and thus the primary impact of climate change: the bog releases even more carbon, which further fuels the greenhouse effect. A positive feedback loop, as scientists call such self-reinforcing processes – or a downward spiral, as the rest of us would say.

What does all of this mean for Le Forbonnet? Will it still glisten in the sun in a hundred years and conjure up a bit of Nordic feeling in the Jura mountains? Buttler and Bragazza contemplate this as they pack up their instruments. “It depends on whether the trees are cut down or not,” Buttler points out. A hundred years ago, this response would have been absurd – trees could hardly have grown there. But they do now and will in the future. The early warning system is already silently sounding.

(bio)