“The forest soil is fairly dry to a depth of 50 cm,” says Elisabeth Graf Pannatier, a soil researcher at WSL. It’s spring in this mixed deciduous forest in the Lägeren mountain range near Wettingen in the canton of Aargau. The scent of fresh wild garlic is in the air. The first leaves are beginning to appear on the low-hanging branches of the beech trees. Kneeling over a gray plastic box, the researcher checks the water levels in three glass bottles. Two of these three bottles, known as lysimeters, contain almost no liquid. If the soil contained more moisture at a depth of 15 cm and 50 cm, the collection devices would have sucked water in from the soil through the vacuum. The third bottle, however, contains about two deciliters of light yellow soil water from a depth of 80 cm. “Despite the lack of rain, the subsoil is still damp,” says the researcher. “Taking soil samples here would be destructive. These fixed collection devices allow us to take soil water samples from the same place over a long period of time and analyze them chemically in the WSL lab.” The nutrients that are dissolved in the water are particularly important, as they affect the growth of the trees.

A network of research sites
At the Lägeren monitoring site, researchers record the rhythm of the forest in minute or hour intervals. This research site is part of the Long-term Forest Ecosystem Research Programme (LWF), which WSL conducts as part of the Swiss Forest Monitoring program (Waldbeobachtung Schweiz) along with the Swiss Federal Office for the Environment. The 19 LWF sites across Switzerland represent the most important forest communities and regions, the diversity of soils, and the different levels of air pollution that forests are exposed to.

At most sites, researchers have been investigating how various environmental disturbances like air pollutants, storm damages and extreme dry spells have been changing the forest and its soil since 1994. First, they documented the chemical state of the soils; since then, they have been measuring the quantity and composition of precipitation before it seeps into the soil. Back in the lab, they analyze leaves and needles collected in litterfall samplers. In doing so, they learn which nutrients are returned to the soil. They also collect other important data at regular intervals such as the sap flow and diameter variations of tree trunks and measure meteorological values such as air temperature and solar radiation. The measurements and an observation period spanning more than 20 years are of great importance.

Measuring the forest as a whole
Watching Elisabeth Graf Pannatier as she checks the measurement devices in the forest gives a sense of her interest in the processes going on in the soil and their interaction with the trees and their environment. “We’re now in at the intensive site,” says the researcher. “Here, we measure the same factors several times across a grid covering 16 subareas. The numerous individual measurements
show the spatial variability, and the average values are representative of the entire area.” When the researchers put all of this information together over a period of many years like the pieces of a puzzle, they can assess whether temporal changes affect the entire area. Individual series of measurements reveal long-term trends, making it possible to identify, for example, the relationships between the chemical quality of rain and that of soil water. For example, the sulfate concentration in soil water has decreased significantly as a result of improved air quality. Thanks to a reduction in the amount of sulfur in fossil fuels used in industrial furnaces and heating equipment, sulfur dioxide emissions
have also dropped sharply since 1980. By contrast, nitrogen emissions into the air remain high and often lead to high nitrate concentrations in the soil. This results in a loss of nutrients because the calcium, magnesium and potassium that are dissolved in the soil water seep into the groundwater or runoff with the nitrate and thus disappear from forest ecosystem. This can result in a gradual depletion of the soil, which in turn impacts plant growth.

The researchers at WSL provide much of this data, which is collected in accordance with internationally standardized methods, to colleagues abroad – primarily as part of the European Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). At the same time, the LWF researchers have access to data from some 800 measuring stations throughout Europe. “This way, we can compare the trends found in Switzerland with the trends in other regions,” says the researcher with enthusiasm.

From soil water to tree growth

Thanks to technical developments, new soil measurement instruments are constantly shedding light on forest soils. “During the dry summer of 2003, we couldn’t measure how much water was still available for trees in Switzerland’s low-lying areas. The soil there was so dry that it was beyond the measurement range of the traditional tensiometer, which measures the soil moisture tension in the soil,” explains the soil expert. “But now we have electronic soil sensors.” These enable researchers to conduct research in much dryer areas and to measure the soil dryness at which trees stop growing. This is important information in view of climate change, as droughts and heat waves are likely to become more frequent.

Finally, thanks to the research at LWF sites researchers have learned a lot over the last two decades about how pollutants, droughts and climate change are affecting the forest ecosystem. “We expect that we still have a lot to learn about soil activity and the metabolic processes going on there. We’re therefore entering uncharted territory, and as a soil researcher this is very exciting for me,” says Elisabeth Graf Pannatier enthusiastically as she closes the box of lysimeters with the day’s readings.