WSL MAGAZINE

DIAGONAL

FOCUS

With shovel and lab coat: WSL's detectives at work

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Swiss Federal Institute for Forest, Snow and Landscape Research WSL

EDITORIAL

Dear Reader
Researchers and detectives have a lot in common: they observe, ask questions and patiently collect evidence, often over long periods of time, so that they can uncover the undetected. But WSL researchers are not trying to catch criminals, but rather to shed light on complex interrelationships in the natural world. This requires forensic methods – for example, using minute traces of DNA to determine which living creatures were at a 'crime scene' (for more on this, see page 14).
However, those who expect that environmental detectives will always be able to solve the big puzzles immediately have misunderstood the nature of research. Research takes time and involves many small steps to reach a goal. Perseverance and continuity are important if we want to know how climate change, pollutants or habitat interventions are changing our environment. Looking only once is not enough. We need to look again and again. WSL has, for example, been observing the state of the forest for over 25 years in its long-term forest ecosystem research – and will continue this and other 'detective work' in the future.

Beate Jessel
Director WSL

FOCUS

Environmental detectives

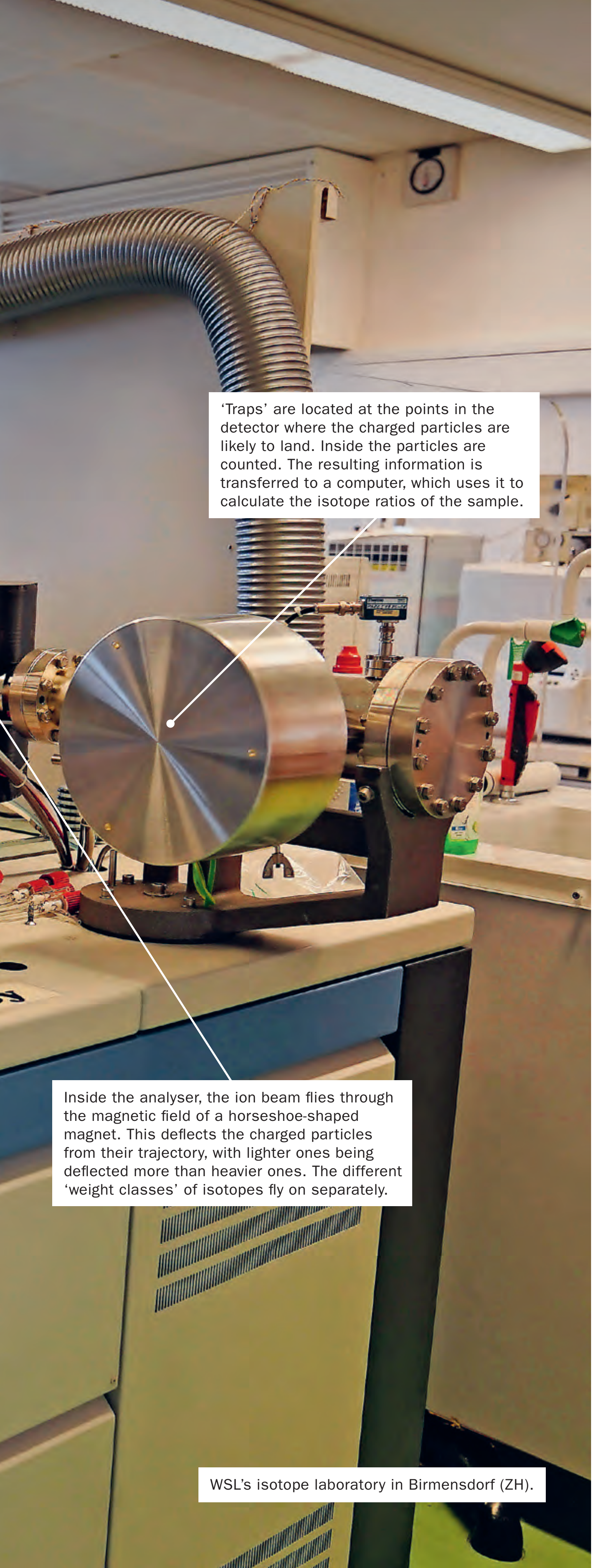
KEY TOPICS

PORTRAITS

SMALEST PARTICLES In WSL's isotope laboratory, researchers become detectives: they can trace invisible food webs or reconstruct the path water takes to get into a tree.

Where researchers sort atoms

A mass spectrometer for analysing different types of atoms – so-called isotopes – consists of three main components. In the first, the ion source, the particles are electrically charged, accelerated and concentrated into an ion beam.



WSL's isotope laboratory in Birmensdorf (ZH).

Photo: Stephanie Kusma, WSL

In the grounds of WSL in Birmensdorf, there is a small forest with a twenty-metre-high beech tree. Its smooth grey trunk is almost too wide to put your arms around. The tree stays firmly attached to the ground with the help of its strong roots. It's easy to imagine that they supply the tree with water from deep down in the earth.

This is not, however, what happens. Rather, beech trees get more than half of their water from the top five centimetres of soil. Even during a severe drought, when this thin top layer dries out, the tree does not manage to compensate for the loss by taking up more water from deeper layers.

Arthur Gessler, a forest ecologist at WSL, was able to demonstrate this by analysing so-called stable isotopes – distinct atomic varieties of an element that differ in mass. Isotopes can be used like a kind of 'marker' – in this case to study the transport of water into the tree.

Lighter molecules evaporate more easily

In nature, isotopes occur in a certain ratio to each other. In soil water, for example, they form a gradient because water molecules that contain the common oxygen isotope ^{16}O are lighter than those with the much rarer isotope ^{18}O. Since the lighter isotopes evaporate faster, the water in the upper soil layers contains proportionally more of the heavy oxygen isotopes and fewer of the lighter ones than the soil water from deeper layers.

Arthur made use of the way water is 'marked' to compare the ratios of oxygen isotopes at different soil depths with the ratio in the trunk of the beech tree. From these comparisons he was able to deduce that the water in the tree must come mainly from the topsoil.

"Our study clarifies why beech trees react so sensitively to drought," the ecologist explains, "as well as why they can recover so quickly." The isotope analyses revealed that the roots had not suffered any lasting damage despite weeks of drought. It seems they were able to suck water out of the topsoil again just a few hours after heavy rainfall.

Arthur determined the isotope ratios in the water directly in the forest using a novel online-method. This is usually done in WSL's isotope lab, where there are several so-called mass spectrometers. They separate the different isotopes in a sample according to their mass. By comparing the measurements with standardised samples, the researchers can determine the isotope ratio in their study material.

For more information on tree-ring research at WSL, see: *www.wsl.ch/year-ring-research*

WSL's 'Detective Office Isotope Laboratory' was moved from the Paul Scherrer Institute to WSL in 2017, and was at first jointly operated. Since 2019, WSL has been running it alone. However, it is not only open to WSL researchers. "We are also very happy to support projects from other institutions," says Matthias Saurer, the head of the laboratory.

In the laboratory, isotope analyses are carried out not only of oxygen, but also of hydrogen, carbon and nitrogen. Since these elements occur in all organisms, researchers from a wide range of disciplines use isotope analyses. The forest entomologist, Martin Gossner, for example, works mainly with nitrogen at WSL. He is studying the food web in deadwood, i.e. finding out more about who eats who (or what) in a dead tree.

These food webs play an important, but largely invisible, role in the forest ecosystem and are involved in the decomposition of deadwood. "In order to understand whether and how the management of a forest affects these food webs, and why some species are becoming rarer and others suddenly more common, you have to know how the organisms relate to each other and inter-

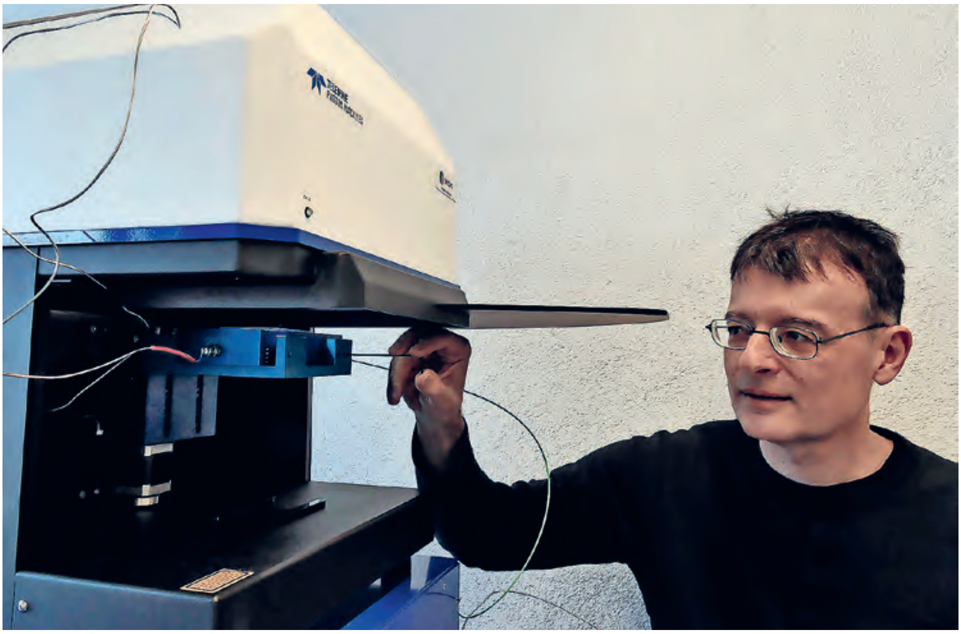


Photo: Stephanie Kusma, WSL

Matthias Saurer, the head of the isotope laboratory at WSL, with the laser ablation device. A sample of wood has been placed in the blue chamber. The thin tubes are for supplying and removing gas.

Wood from a Jatobá tree in Costa Rica. Bright lines and pores are clearly visible, as are the burn holes from the laser ablation device. The holes are in a neat row, each 0.1 millimetres in diameter.

act," says Martin. These interrelationships can be reconstructed through analysing isotopes.

Dozens of measurements in a single annual ring

Isotope analyses also allow researchers to obtain information about past climates from old wood. Since each tree ring corresponds to exactly one calendar year, examining the isotope ratios in a tree ring provides information about precisely that year. Combining the ratios of two carbon and two oxygen isotopes with each other, for example, yields clues about drought occurrence. If the proportion of 'heavier' isotopes is large, this indicates that the temperatures were high and there was little precipitation.

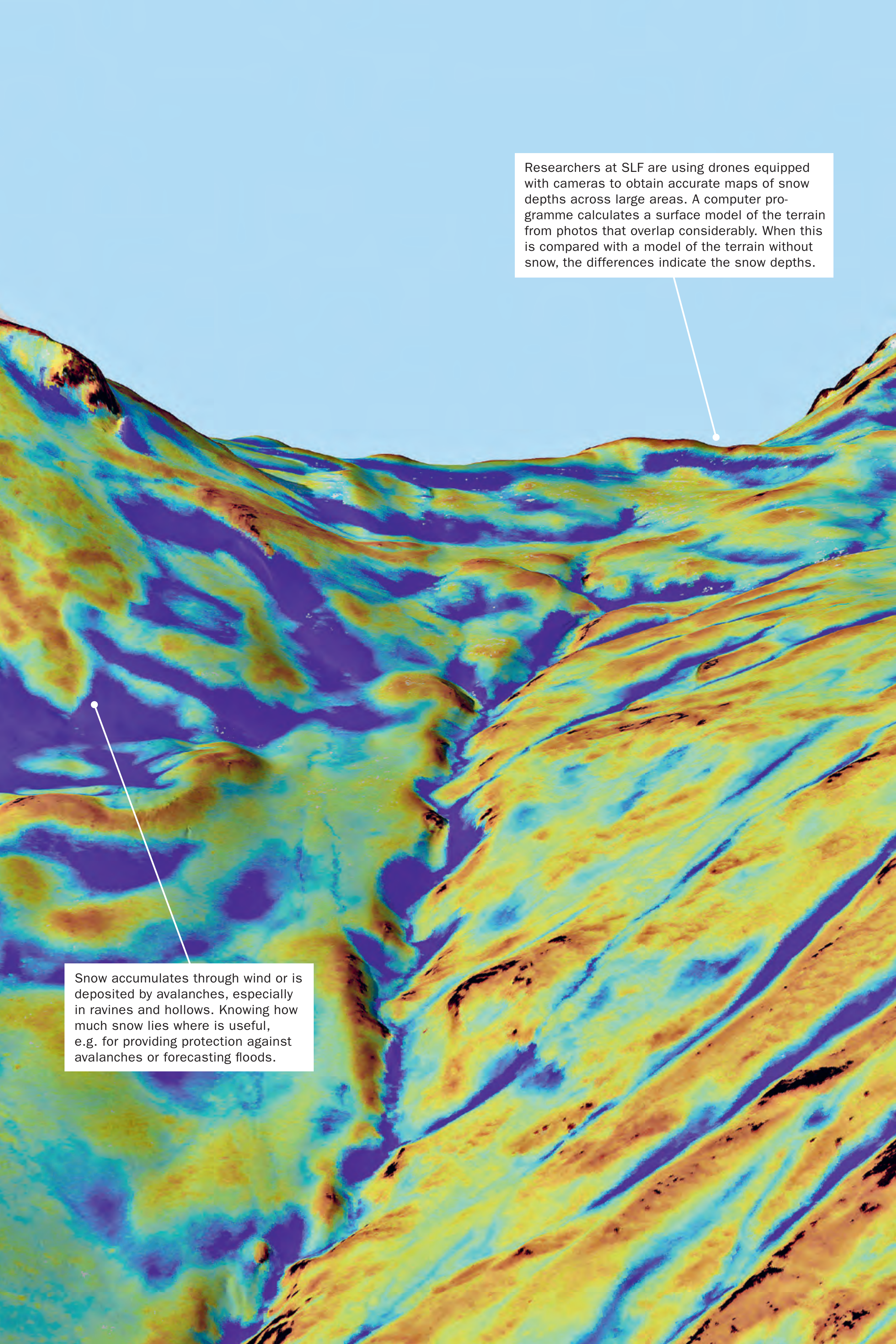
For even more precise analyses, the isotope laboratory has a very special device. "The so-called laser ablation device here is one of the first in the world to be used in this area of research," says Matthias Saurer. It burns tiny holes into the wood with high precision. The resulting 'smoke' and the isotopes it contains are then analysed in the mass spectrometer.

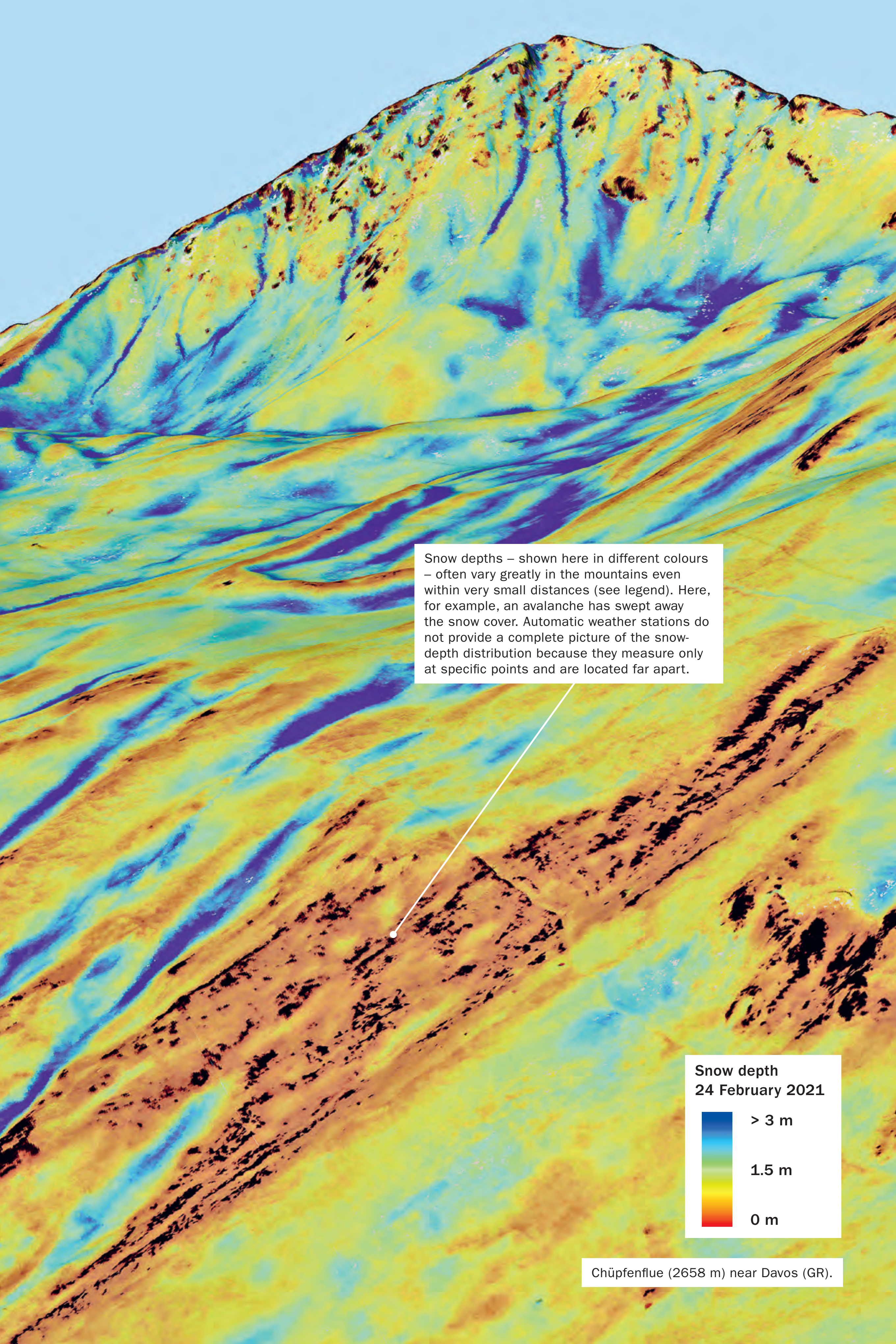
"With the laser ablation device, dozens of analyses can be carried out on just one tree ring," Matthias explains. "This means that, when reconstructing past climates, you no longer just say: 'This year was dry', but rather: 'In this year, the months May and June were dry'." Previous methods did not allow such differentiated conclusions. This new data, which is at finer resolutions, can help make climate models, for example, more accurate.

Samples of tropical woods are currently being examined in the laboratory with this method. Tropical wood has no annual rings, which is why it is difficult to determine its age. "But the wood has other structures, such as light bands," says Matthias. With the high-resolution measurements, the researchers want to find out whether, for example, the visible structures represent dry or rainy seasons.

This would provide access to a wealth of climate and weather data. "The tropics have been relatively poorly studied in terms of such information," says Matthias. "Yet we need to know more about how climate change is affecting the tropics because they cover such a vast area." Isotope analysis could help fill in this information gap. *(kus)*

For more information about the isotope laboratory, see: *www.wsl.ch/ isotope-laboratory*


Researchers at SLF are using drones equipped with cameras to obtain accurate maps of snow depths across large areas. A computer programme calculates a surface model of the terrain from photos that overlap considerably. When this is compared with a model of the terrain without snow, the differences indicate the snow depths.
Snow accumulates through wind or is deposited by avalanches, especially in ravines and hollows. Knowing how much snow lies where is useful, e.g. for providing protection against avalanches or forecasting floods.



Snow depths – shown here in different colours – often vary greatly in the mountains even within very small distances (see legend). Here, for example, an avalanche has swept away the snow cover. Automatic weather stations do not provide a complete picture of the snow-depth distribution because they measure only at specific points and are located far apart.

Chüpfenflue (2658 m) near Davos (GR).

PERMAFROST **Detecting hidden ice.** For 25 years, researchers at the WSL Institute for Snow and Avalanche Research SLF have been studying the substrates high up in the mountains. Their aim is to locate and monitor permanently frozen ground.

If you want to build infrastructure, you have to know what the substrate is like. This is not always easy to find out, especially in mountainous areas with permafrost, i.e. soils whose temperature remains below freezing all year round. In summer, however, the top layer of these substrates warms to above zero degrees Celsius. The ice melts and water flows through the soil. These processes change the substrate structure and thus the load-bearing capacity of the subsoil. Infrastructure in the mountains such as railway stations, restaurants and avalanche barriers may become unstable as a result. Climate change is exacerbating these problems and leading to increases in the thickness of the seasonally thawing and freezing active layer.

SLF permafrost and ground ice map: *www.slf.ch/pgim-en*

Locating permafrost soils is, however, difficult because permafrost is an invisible, thermal phenomenon. SLF researchers therefore began, in 1996, drilling boreholes into the permafrost in the Swiss Alps and equipping them with temperature sensors to depths of twenty to fifty metres. There are now over thirty boreholes, all of which are protected from the weather by a covered shaft. Nine of these boreholes are part of the Swiss permafrost monitoring network PERMOS, which is responsible for monitoring permafrost throughout Switzerland. SLF is one of the six PERMOS partner institutes and manages, together with the University of Fribourg, the monitoring network. Most of the measurement sensors send their data automatically to SLF, but in summer the researchers have to go to some of the boreholes high up in the mountains to collect the data.

For Marcia Phillips, head of the Permafrost Group at SLF, it's a bit like being in a thriller: "We never know what kind of condition the boreholes and the measuring instruments will be in when we arrive. On one occasion we found a huge boulder had rolled down and blocked a shaft cover. We had to have the rock blown up." Once the recorded data has been collected, the detective work proper can begin. "We try to understand how, for example, the snow cover or the air temperatures influenced the temperature fluctuations in the soil."

To complicate matters, there is a time lag between external temperature fluctuations and changes in the permafrost temperatures. Warm summers are only registered in the soil data months later. The researchers also see a delay before the influence of climate change becomes apparent in their data. What is clear, however, is that soil that used to be permanently frozen is now thawing more frequently to greater depths.

Substrates under current

One important bit of information cannot, however, be derived from these measurements. When the ground temperature is zero degrees Celsius, the soil

Temperatures are measured in mountain substrates in over thirty boreholes in the Swiss Alps.

may contain both ice and water. This can influence the stability of the soil because ice is a very plastic material that can change shape and creep. The SLF researchers therefore rely on other measurement methods to detect ice in the soil. In collaboration with Jacopo Boaga, a geophysicist at the University of Padua, they tested electrical resistivity tomography, among other methods, on the Schafberg above Pontresina (GR) in 2019. This method, which is carried out at the ground surface, provides information on the characteristics of the substrate.

For the measurements, stainless steel electrodes were driven half a metre deep into the ground at regular intervals and an electric current was passed through them. The researchers were then able to determine the composition of the substrate from its conductivity, which differs for ice, water, air and rock.

Fieldwork in the mountains: *www.slf.ch/rockglacier*

Permafrost can also be detected indirectly from the shape of the terrain. Rock glaciers, a typical landform associated with mountain permafrost, are often found at the base of steep slopes. They consist of a mixture of debris and ice that slowly creeps downhill. Robert Kenner, a surveyor at SLF, therefore uses a terrestrial laser scanner, aerial photographs and other methods to quantify how the terrain surface is changing in the mountains.

Robert combined the data from all the measurements to create SLF's permafrost and ground ice map. It distinguishes between ice-rich and ice-poor permafrost and is very much in demand. According to Marcia: "It provides engineering firms and construction companies with indications about where the ground might contain permafrost. Before the first sod of earth can be turned in a construction project, however, further in-situ information about the site will be needed." *(lbo)*

Photo: Anouk Widmer

POLLUTION **Tracking pollutants and environmental toxins.** To protect people and the environment, WSL researchers monitor and quantify the pollutants they detect in the forest and other ecosystems with the support of WSL's central laboratory.

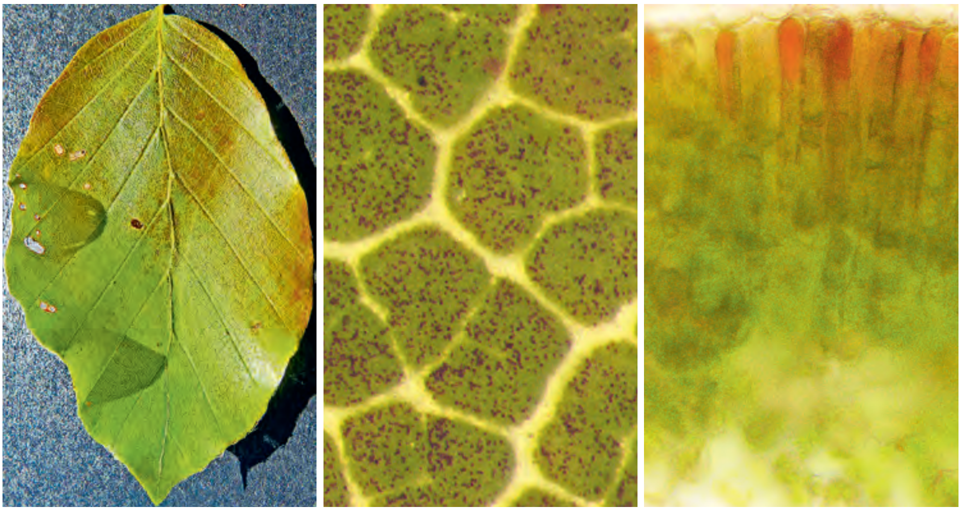
Invisible but everywhere: pollutants such as nitrogen oxides, chlorine, heavy metals, ammonia or nitrates are widespread. They get into the air through the combustion of oil and petrol, or through industry and agriculture. Rain washes them into the soil where they are absorbed by living organisms. Some toxins attack plant cells, while others disturb material flows in the natural environment. This means analysing pollutants is essential in ecological research.

WSL's central laboratory is where this all comes together. Samples taken from forests and fields are put through various analysis steps here, such as with this automatic sampler. It is sucking in a small amount of solution and spraying it into a grey device. Inside a small green flame of argon plasma reaches a temperature of 10'000 degrees – making it the hottest place at WSL. The device, an atomic emission spectrometer, can detect positively charged particles, including heavy metals such as lead, cadmium, copper and zinc. Depending on the concentration, they may be very toxic.

The liquid solutions come from a forest floor somewhere in Switzerland. Stephan Zimmermann, a soil researcher at WSL, is currently collecting soil samples at various depths on over two hundred test plots. He is repeating the systematic, Switzerland-wide soil inventory that was part of the 1993 Sanasilva forest health inventory. "With our data, we can now estimate the state of the soil at most forest sites in Switzerland," he says. This information provides

The soil across the whole of Switzerland is being sampled again. This should enable, for example, the identification of sites contaminated with nitrogen.

Photo: Cédric Bührer, WSL



Ozone, an aggressive gas, damages cells in leaves. The damage patterns serve as bioindicators for high ozone levels.

a basis for deciding on political measures, for example setting stricter limits. "Repeating the inventory will allow us to see what changes have taken place."

The consequences of industrial production

Chemicals, exhaust fumes and over-fertilisation are the consequences of two hundred years of industrialisation, which markedly intensified in the 20th century as the population grew and prosperity flourished. Since the 1970s, the general public has gradually become more aware of the side effects. At that time, Theo Keller and Madeleine Günthardt-Goerg were two of the first pollutant detectives at WSL. Among other things, they began environmental monitoring in 1971, assessing damage to beech leaves to monitor the effects of chlorine and heavy metals from a waste incineration plant in Canton Glarus.

For more on LWF, see *wsl.ch/lwf-en*

When the Chernobyl nuclear reactor exploded in 1986, the importance of regular monitoring of pollutants became particularly apparent. A cloud of radioactive caesium-137 spread over northern and eastern Europe, and in Switzerland radioactive fallout fell on Ticino, the Jura and north-eastern Switzerland. It turned out to be a stroke of luck that soil samples had been collected from all 12'000 test sites during the first Swiss National Forest Inventory from 1983 to 1985. After the 1993 soil inventory mentioned above, it was possible to compare the caesium levels with those before the accident. According to Stephan, the findings confirmed that, in those places where it had rained at the time, the caesium was still in the topsoil. This was further support for taking such precautionary measures as not eating any mushrooms collected in those areas.

Pollutants in the forest

It was also in the 1980s that the spectre of forest dieback started causing alarm: Were air pollutants making the trees sick? Intensive monitoring of pollutant depositions and the health of forests began throughout Europe and has continued to this day. Switzerland contributes, among other things, the data from the nineteen test plots of the Long-term Forest Ecosystem Research (LWF) programme, which has, since 1994, meticulously recorded concentrations of pollutants in the air, water, soil and plants to establish the material flows.

Photos: Pierre Vollenweider, WSL

Since then, WSL's central laboratory has had a standing order, so to speak, to analyse the samples from the LWF sites. Negatively charged ions can be detected, using so-called ion chromatography, in extracts from soil, plant and needle samples, as well as in rain- and soil-water. Depending on the quantity involved, chlorides, nitrates, phosphates and sulphates can act as either fertilisers or pollutants.

The LWF programme confirmed that the air pollution control measures of the 1990s had been successful. These included making it compulsory to use catalytic converters in cars, desulphurised oil for heating and flue gas filters in industry. As a result, sulphates, one of the sources of 'acid rain', decreased considerably, as did aluminium in soil water. These decreases could be shown in Europe-wide forest monitoring data, which includes LWF findings.

Nitrogen depositions in forests have also dropped, but they are still too high. The main sources of these air pollutants are traffic and agriculture. Although nitrogen is actually a nutrient, very high depositions can inhibit tree growth, according to Sophia Etzold, an LWF staff member. "An imbalance of nutrients can throw a forest ecosystem out of equilibrium."

According to the Swiss Forest Report 2015, the critical loads for nitrogen are still exceeded on about ninety percent of the forest area – despite improvements. Here Stephan Zimmermann's soil inventory provides useful information: "When we know where large depositions occur, measures can be taken there," he says. The Federal Office for the Environment (FOEN) is conducting pilot tests to treat particularly acidified forest soils with lime. "However, reducing emissions at the source must be the main strategy," says Stephan.

This approach has worked with heavy metals. Thanks to stricter environmental regulations, heavy metal emissions have decreased and these substances are no longer at the forefront of monitoring. WSL's central laboratory has scaled down its heavy-metal analytical capacities accordingly. "We are a service provider," says Daniele Pezzotta, head of the central laboratory. "We focus on what the researchers want us to analyse."

However, heavy metals are extremely persistent, so the problem has not been solved. In an ongoing study in Canton Valais, WSL microbiologist Beat Frey is investigating how mercury affects the diversity of soil microorganisms. This heavy metal entered the environment from the Lonza factory in Visp between 1930 and 1990. The results surprised Beat: "The soil microflora can adapt to the high mercury levels in the soil in the long term." The microorganisms convert the toxic soluble mercury in the cells into a gaseous form and emit it.

Diagnosing poisons on the basis of the damage pattern

One still unsolved pollution problem is ozone. The aggressive gas is formed near the ground under solar radiation from nitrogen oxides in traffic exhaust. Leaves and needles damaged by ozone show typical yellowish to reddish-brown spots and discolouration. "The diagnostic potential of ozone injuries was recognised quite early," says Pierre Vollenweider, a plant physiologist at WSL. "Today, they are systematically used in all forest monitoring programmes in Switzerland and Europe as bioindicators of ozone stress."

The work of the WSL pollutant detectives does not end with documenting damage and pollutant concentrations. Detective work in science also in-

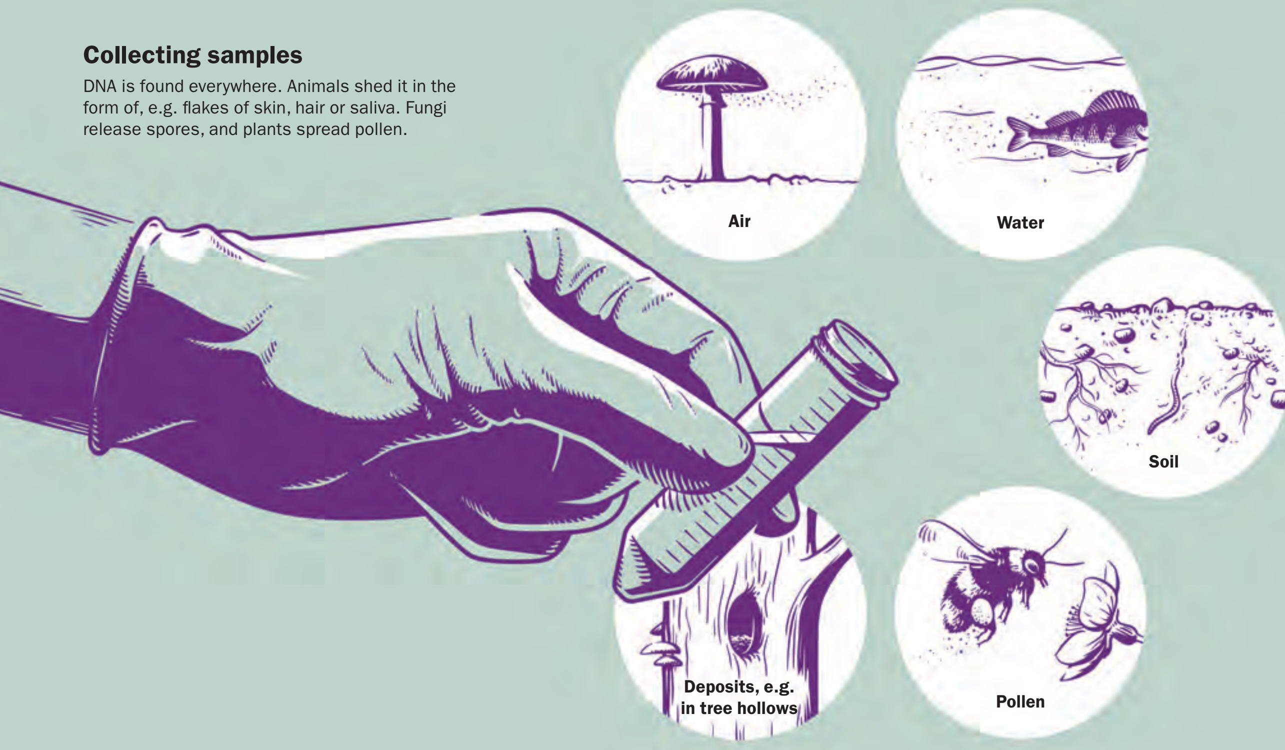

A climber on a spruce at the LWF Seehornwald site near Davos. She is collecting needles for laboratory analysis.

volves bringing together and interpreting the various measurements and results. This is sometimes like putting together a jigsaw puzzle, but the complex task then provides policy-makers with a basis for taking the right measures. *(bki)*

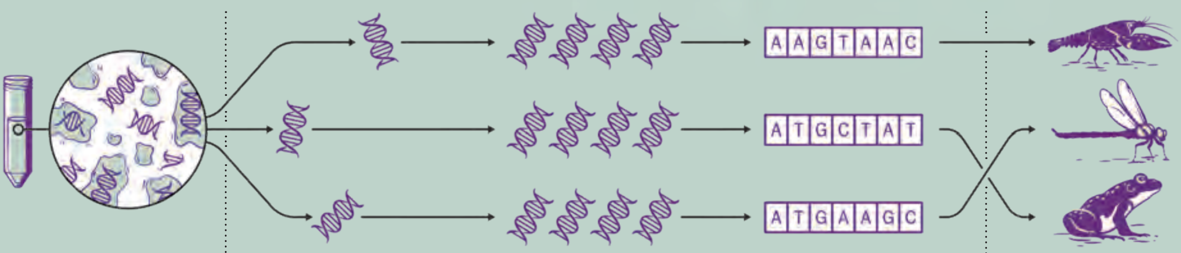
INFOGRAPHIC **Who was here?** Every organism leaves tell-tale traces of its genetic material in the environment. WSL researchers analyse this DNA to identify animals, plants, fungi and microorganisms.

Collecting samples

DNA is found everywhere. Animals shed it in the form of, e.g. flakes of skin, hair or saliva. Fungi release spores, and plants spread pollen.



From DNA to the organism



In the field

The sample – e.g. water from a pond or a soil sample – contains DNA, some of which is still within the cells.

In the laboratory

The cell material and other impurities are removed, but DNA fragments from different species remain – often in only tiny amounts.

The DNA is multiplied millions of times using the so-called PCR method to obtain enough material for analysis.

The pieces of DNA are sequenced, i.e. their genetic code, which is distinct for each species, is deciphered.

On the computer

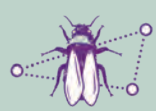
The sequences are checked against a database to identify the associated species or species groups.

What the method is used for

Recording the distribution of fungal species for the 'Red List'

Detecting invasive species early, e.g. the ash bark beetle

Comparing species communities in two different habitats



Identifying networks of pollinators and flowers

Detecting which amphibians live in water bodies

Infographic: Michael Stünzi und Daniel Röttele, infografik.ch; Data and text: Markus Schlegel, Claudia Hoffmann

ONE-TWO **"Environmental DNA has huge potential."** Need to identify lots of fungi quickly or find unknown species? With environmental DNA you can. The mycologist Andrin Gross and the amphibian expert Benedikt Schmidt discuss when it makes sense to use it.

What is environmental DNA?

BS: This is best explained with an example. When you go to the swimming pool, you're usually glad that the water there has been cleaned as it would otherwise be full of stuff like traces of skin, mucus or faeces. But as a biologist you can use all these traces because they contain DNA, i.e. genetic material. Samples of the water can be taken to determine the species that is the source of the DNA in them (see Infographic, p. 14). Most of the DNA sampled in a swimming pool would come from humans, whereas the DNA from a pond would include all species that visit or live in it.

AG: But it's not only with water that this works. The DNA can come from any environmental sample, including from water, soil, river sediment or a glacier core. All these samples contain genetic material – hence the name environmental DNA, or eDNA from the English 'environmental DNA'.

What sort of research questions can be clarified in this way?

BS: The question is always whether certain organisms occur in a particular habitat. It could be about whole groups or individual species.

AG: This is why one possible field of application for eDNA is species monitoring, which involves finding out which species occur where. Such data is needed for the Red Lists, for example, which rely on observation data to estimate a species' endangerment status.

Can't you just go out to the field and look for the species?

AG: In principle, yes, and that's what people are doing at the moment. But the fungi kingdom, which is the focus of my research, is extremely species-rich. In Switzerland alone, almost 10,000 species have been identified so far. The actual number is probably much higher. So eDNA has huge potential. When you are in the field doing monitoring work, you don't see many fungal species because they are too small. As for the rest – you need at least five specialists to identify them. The effort involved is enormous. It's different with eDNA: in just one environmental sample you can – with very little effort – detect hundreds of species simultaneously.

BS: eDNA also helps save time and money when monitoring amphibians. For example, we collect distribution data on amphibians to see how well they are doing in Switzerland. It can be difficult to see into a pond if it has a wide belt of reeds and is full of water plants. This makes searching tedious. If, however, you work with eDNA, you

Benedikt Schmidt is an expert on amphibians at the Coordination Centre for Amphibian and Reptile Conservation in Switzerland (info fauna karch) and head of a research group at the University of Zurich.

Andrin Gross works as a mycologist at WSL and is responsible for the national data centre 'SwissFungi'.

can just take a water sample and see if there is any amphibian DNA in it. That is much easier.

Are there any other advantages?

BS: Yes, for animal welfare, for example. Suppose we want to know if a skin fungus that is dangerous for amphibians is present in a pond, we can use eDNA to analyse a water sample instead of catching the amphibians and taking skin swabs. With eDNA you can potentially also obtain a lot of information in one go, whereas in classical monitoring we collect only data on amphibians. When you take eDNA water samples, on the other hand, you could also identify the dragonflies living in them. That's something I'd like to do.

SwissFungi: *swissfungi.wsl.ch*

AG: Another advantage is that you sometimes find more unknown species in a particular fungal group. In our eDNA studies, for example, we have found many more coral fungi – fungi with coral-like fruiting bodies – that are genetically distinct but that have not yet been described. Apparently there are more species around than we know, and we should have a closer look.

BS: Among amphibians, the water frog is one such example. There are four or five invasive water frog species and two native ones. One of them is the result of a cross between two other frog species, and they can all mix with each other. You can't get anywhere using just their external characteristics. Using eDNA methods is very valuable because you can get much clearer classifications than would be possible in the field with conventional methods.

If eDNA has so many strengths, is classical monitoring still needed at all?

BS: For us it is. eDNA is for us simply another tool which it makes sense to use in certain situations, such as with the water frogs or in an overgrown pond. If you can see well into a pond, classical monitoring is still better. It provides valuable additional information, for example about whether there are juveniles or how large the population is.

AG: This limitation is less relevant for us because counting fungal individuals with classical methods is difficult.

Can eDNA be used to discover very small populations that would otherwise have been overlooked?

BS: No. Rare species and small populations are sometimes even harder to find with eDNA than with classical methods. If you have spent a lot of time catching a single newt in a pond, its genetic material may not be detectable at all. One reason is that the DNA is not evenly distributed in the water and therefore there may be no DNA in the sample you have taken.

AG: Yes, that's a problem for us too. When we catch fungal spores from the air in a spore trap, we often don't find the rare species either. This is because the vast majority of spores fall to the ground within a few metres of the fruiting bodies of the fungi. You therefore have to think carefully about where to place the spore traps.

"eDNA helps save time and money."

Spore traps like the passive one on the left in the photo and the active one on the right are used to 'catch' fungal spores from the air. The genetic material they contain is then analysed in the laboratory.

Are there sometimes surprises in eDNA detective work?

BS: Yes, we've certainly had surprises. For example, you get the species list from the lab and see a newt species listed that you've never seen before at this location. But then the question is whether the finding is correct. How many DNA sequences of this presumed newt species do I need to feel confident that the identification is correct? We are working on defining such threshold values. When I have a newt in my hand, such questions do not arise, even though misidentifications do occur.

AG: There may also be surprises if the eDNA data is evaluated again at a later date with better reference databases. The reason is that we can only identify species with the help of eDNA if their genetic fingerprint is stored in a database. So far, however, we are a long way from having the fingerprints of all species of fungi. We are currently working on a WSL project to compile the genetic fingerprints of all the fungi on the Swiss Red List, i.e. over nine hundred species. Once we have these, we can examine earlier eDNA records to see whether a species was already present at that time. You can, so to speak, go back in time. This is a huge advantage of eDNA and means that the data sets have added value. *(kus)*

Karch: *www.karch.ch*

Photo: Markus Schlegel

ARTIFICIAL INTELLIGENCE **When a machine learns to predict avalanche danger.** A computer can now – after 'training' with an SLF researcher – assess the regional avalanche danger in many situations almost as well as experts.

Every day the avalanche forecasters at the WSL Institute for Snow and Avalanche Research SLF rely not only on their extensive experience to assess the avalanche danger. They also process huge quantities of data on the weather and on how the winter is developing. Back in the 1990s, attempts were already being made to analyse data automatically to support the forecasts, but none really worked because the data and computing power available were too limited.

The data researcher Cristina Pérez Guillén has now achieved a breakthrough in collaboration with the avalanche warning service of the SLF and the Swiss Data Science Center. "We can automatically predict the regional avalanche danger level about as well as people can," says the Spaniard. She tried out different kinds of machine learning to enable the computer to detect correlations between the weather data and the corresponding warning levels that the human forecasters predicted. For example, it learned to make its own forecasts from data on the basis of information from twenty previous winters. Cristina found that the learning approach known as 'random forest' seems to work best. She presented the computer with measurement data from two other winters that had not been used in the learning process, and got it to create avalanche forecasts using the new data.

Only suitable for dry avalanches

With machine learning, it is not really possible to figure out how and what the computer learns. But Cristina has, at least, been able to discover which parameters the machine considers particularly relevant. And lo and behold: they are essentially the same factors that human forecasters also consider central – based on their understanding of the processes involved and past experience. They include, for example, the amount of new snow and snow drifting.

Automatic forecasts still have weaknesses in handling the so-called 'old snowpack problem', which is an issue particularly in the inner Alps. The model is also only suitable for dry avalanches. The avalanche warning service has already evaluated the new method, and it tested it in operation during the winter of 2020/21 and last winter. Thomas Stucki, the head of the avalanche warning service, says: "The computer helps to improve the consistency of the forecasts and should provide us with a valid second opinion in the future. We humans can then devote all the more attention to translating the results into warnings that people can understand." It's therefore unlikely that the forecasters will become unemployed. *(bio)*

Photo: Bruno Augsburger, Zürich

Chasper Buchli, Davos

"For me, the Flüela Pass is very special because it connects Davos, which is where I live and work, with the Engadine. I grew up there in Sent and have strong ties to the region. As soon as I get to the Engadine, I speak my mother tongue, Romansh."

FASCINATED BY NATURAL HAZARDS

The responsibilities of the electrical engineer, Chasper Buchli, include maintaining and developing some measuring stations in the Swiss Alps. The stations measure such features as snow depth, temperature and wind speed. This data is important for research, but also indispensable for the avalanche bulletin. Chasper finds working with natural hazards exciting. "I like being outdoors and enjoy being able to alternate between office- and fieldwork." *(sni)*

FOREST

Recreation in forests: taking people into account in the National Forest Inventory

Two researchers discuss with a passer-by what he likes about the forest.

Photo: Simon Speich, WSL

Forests have to fulfil many requirements. They need to provide timber and protection against natural hazards, promote biodiversity and serve as a place for recreation. Two large monitoring programmes at WSL have been tracking the development of these forest functions for many years. One, the National Forest Inventory NFI, monitors the Swiss forest's physical condition and changes over time, whereas the other, the Sociocultural Forest Monitoring (WaMos), examines the public's relationship with the forest.

WaMos and previous studies have shown that a forest's physical characteristics contribute to its visual attractiveness and recreational value. "But NFI has, up until now, paid little attention to recreation even though it is an equally important forest function," says Tessa Hegetschweiler from WSL's Social Sciences in Landscape Research Group. The project 'WaMos meets NFI' serves as a 'bridge' between the two programmes. In one part of the study, the research team asked roughly a thousand passers-by at fifty highly frequented NFI sites during winter and summer what they liked about them. In another part of the study, one thousand people rated photos of the areas around NFI plots in an online survey.

The results are in line with those of other studies: structurally diverse forests are popular, and so are forests where the shrub layer is not too dense. In contrast, blackberries, ivy and storm damage score poorly, whereas lying trees seem to meet with more acceptance. This is the first time that the attractiveness of a forest has been linked to real NFI data and locations.

Switzerland is thus one of the first countries to include a social dimension in its forest inventories, which were originally geared more towards timber production. According to Christoph Fischer, head of the NFI scientific service, forest managers are very interested in this research: "For them, the recreational function is becoming much more important." *(bki)*

www.wsl.ch/en/wamos-meets-lfi

FOREST

Boom in energy wood: how does it affect nutrients in forest soil?

Fossil fuels are increasingly being replaced by renewable raw materials such as wood. This means that forest enterprises today tend to harvest not only tree stems, but also parts of the crown or even entire trees for energy production. The problem is that, in some locations, too many nutrients are being removed from the forest, which has negative effects on soil fertility.

This is why WSL researchers launched – in June 2020 – a project to investigate the nutrient budgets in two beech stands in Zurich. Their aim is to be in a better position to assess where – and how much – wood can be harvested. This involves measuring, among other things, the nutrient content of various tree elements, such as twigs or branches, and their share in the overall nutrient balance of the forest. The analysis also takes into account other nutrient-input and -output processes that influence the balance, such as the input of nitrogen through air pollution. The researchers have used the data to develop a so-called mass balance model. It estimates how different forms of forest management affect the nutrient ratio in the soil and soil fertility.

"The aim is to provide forest enterprises with a tool for planning their harvests so that they can actively contribute to producing energy wood in a sustainable and efficient way," says Stephan Zimmermann, who is head of the project. The model should make it possible to identify soils with positive nutrient balances where timber harvesting does not endanger soil fertility. It should be available from autumn 2023. *(fga)*

Stephan Zimmermann collecting branches of various sizes to determine their nutrient content.

Photo: Marco Walser, WSL

LANDSCAPE

Can agriculture be both productive AND good for the environment, people and landscapes?

Reuss plain, 1933 (top) and 2020 (bottom): The marked decrease in the number of trees since 1933 is striking. The federal government's campaign in the 1950s to fell fruit trees contributed to the decline, as did the increasing mechanisation of farming and size of fields.

Agriculture in Europe has changed drastically since the 1950s. Significantly more food per area can be produced today thanks to the application of fertilisers and pesticides, and to larger fields that can be cultivated with machines. This intensification has, however, been at the expense of the natural environment and landscape. Can it be done differently? This is what researchers from WSL, Agroscope and Vrije Universiteit (VU) Amsterdam are now investigating in the European project SIPATH. As Matthias Bürgi from WSL's Research Unit 'Land Change Science' and joint head of the project puts it, the question is: "How can you produce more calories with less negative impact?"

The research team is exploring, among other things, sustainable agriculture intensification in case studies in sixteen regions across Europe. "We are looking at how management has changed in recent decades and what the driving factors behind the changes were," explains Franziska Mohr from WSL's Land-Use Systems Group. Once these have been identified, they hope that legislation and/or subsidies, for example, can be adapted to favour more ecological, but still cost-effective, food production.

Where have all the fruit trees gone?

One of the regions they are studying is the Reuss Valley – a typical agricultural area in Switzerland. Franziska, together with Livia Lehmann, a Master's student at the University of Bern, interviewed ten farmers in the valley aged between 57 and 82 years old. The farmers said there were several historical milestones in the intensification. The first was when flood protection and drainage measures were undertaken during the redevelopment of the Reuss Valley in the 1970s, which created not only new land for agriculture, but also nature reserves. At the same time, a redistribution of property enabled farmers to cultivate adjacent areas. During the following decades, fields and machines became

Photos: Federal Office of Topography swisstopo larger and larger, at the expense of fruit trees and hedgerows.

On the political level, the switch from support for production to direct payments in 1993 was decisive. Subsidies were now linked to ecological conditions such as limiting the amounts of nitrogen fertiliser applied. As one farmer said: "When the milk price dropped dramatically, the direct payments became, of course, a very important source of income."

While some of the changes such as more efficient milking parlours were technical, social trends have also had an impact. Some of the townsfolk who settled in the farming villages complained about the smell of manure. One farmer therefore sold his cattle and started growing Christmas trees. "Stopping producing food for humans is not, however, in line with sustainable intensification," says Matthias Bürgi.

In recent years, the trend has been more towards further market liberalisation. To remain competitive, some farmers have enlarged their farms, while others have had to give them up. Today, subsidy programmes to promote biodiversity allow farmers to focus on increasing species diversity in small sections of their fields rather than on food production, while still earning money. Many farmers have adopted this middle approach. As one said: "We are dependent on good yields and thus intensive cultivation, but we need room for nature too."

What future do we want?

The preliminary conclusion of the project, which will run until 2023, is that the political and economic situations in all the regions in Europe where the case studies took place influence the decisions of individual farmers. Regulatory frameworks should, therefore, take into account the local and regional contexts. "The public should decide what vision it wants for the future," says Franziska. Should robots be used to make production more efficient, with fewer but larger farms? Should more land be ecologically upgraded, which would mean importing more food? "We aim to raise awareness about these trade-offs as a basis for debate," says Franziska.

The project team is therefore developing potential scenarios for intensifying all European agriculture sustainably. These take into account mega-trends such as climate change, population development, stricter environmental regulations and trends in world market prices. For the researchers it is clear that: "in coming decades, profound changes will have to take place in food production and in how we use agricultural land in general." *(bki)*

www.wsl.ch/sipath

LANDSCAPE

In the wild Alps or densely populated lowlands? Where do energy installations fit best?

Renewable energy installations contribute to sustainable energy production. But for people to accept them, they must fit in with the landscape in which they are located. (Photo: Boris Salak, wind and PV park in Lachtal, Austria)

About 750 new wind turbines and solar panels on every third roof in Switzerland – that's what it would take to achieve the targets set for wind and solar power in the Swiss Energy Strategy 2050. Such an expansion of renewable energy will inevitably affect the landscape, so where should energy infrastructure be located, and where does it not fit in? Researchers at WSL have investigated this in a nationally representative online survey "Energy infrastructure in typical Swiss landscapes". One of their findings is that there seems to be a consensus as to where energy installations should be located – and where they do not belong.

"People tend to want to protect untouched landscapes in the Alps, Pre-Alps and Jura from these developments," according to Boris Salak, a researcher at WSL. In areas that already have infrastructure, such as cable cars, energy installations are less likely to be disruptive. The public in Switzerland seem, however, to consider urban areas and agglomerations in the lowlands to be potentially the most suitable 'energy landscapes'.

People's personal experience is important

Among the factors that influence whether people consider energy infrastructure to be suitably located in a landscape or not are their individual attitudes towards the natural environment and the experiences they have had with energy installations. For example, those respondents who view nature as something for humans to use, or who are accustomed to seeing energy infrastructure where they live, were more likely to accept it. Their attitudes to landscapes with en-

Photo: Boris Salak, WSL

ergy installations are also important: do they perceive them negatively as further mechanisation of the landscape or positively as a symbol of sustainability?

The type of installation also plays a role. Respondents viewed energy landscapes with just a few solar panels even more positively than those without any panels. The situation with wind turbines and high-voltage power lines is different. This could be because of the way such structures are 'branded', says Boris: "We often read about problems with wind turbines, whereas solar energy has so far had hardly any negative press."

When planning energy installations, we need to be aware of all these processes, says Boris, and stresses that: "In addition to practical and ecological aspects, the landscape itself and how people feel about it must also be taken into account." Another WSL study on the topic with a regional focus has produced similar findings. "Here, too, involving the local population in decision-making processes as early as possible is also recommended." People want to be heard, according to Boris, who reported that although the survey included the option not to choose any scenario as preferable and thus not to give an opinion, it was hardly ever used. *(kus)*

www.wsl.ch/en/energyscape

LANDSCAPE

Walking for research

Zurich during the rush-hour: one car after another whizzes by. People's front gardens are in full bloom. We go out for a walk, but how relaxing is it? This is what Julia Schaupp, a doctoral student at WSL, is trying to find out. She is investigating the influence of greenery in the surroundings and the noise of traffic on how restful people find walking in the forest or in the city.

For her research, she gets the people she is testing to go for a walk. She uses physical stress indicators such as cortisol levels and questionnaires to determine their stress levels before, during and after the walk.

Julia's study is part of a project on noise in green spaces that WSL is conducting together with the Swiss Federal Laboratories for Materials Science and Technology Empa. "We want to find out how noise affects recreation," explains Silvia Tobias, the project leader, "and which acoustic and landscape qualities promote outdoor recreation."

The researchers are examining these questions from various points of view ranging from laboratory experiments on people's stress responses through to a nationwide survey on the the characteristics of landscapes that support restoration from stress. Julia's field study acts as a kind of 'mediator' between the laboratory and the real world.

As urbanisation increases, it is becoming increasingly important to find out more about how noise affects the restfulness of green spaces. The results of the project should be available by 2024. They should help in, for example, deciding how best to preserve or enhance tranquil green spaces in and around cities. *(kus)*

www.wsl.ch/restore

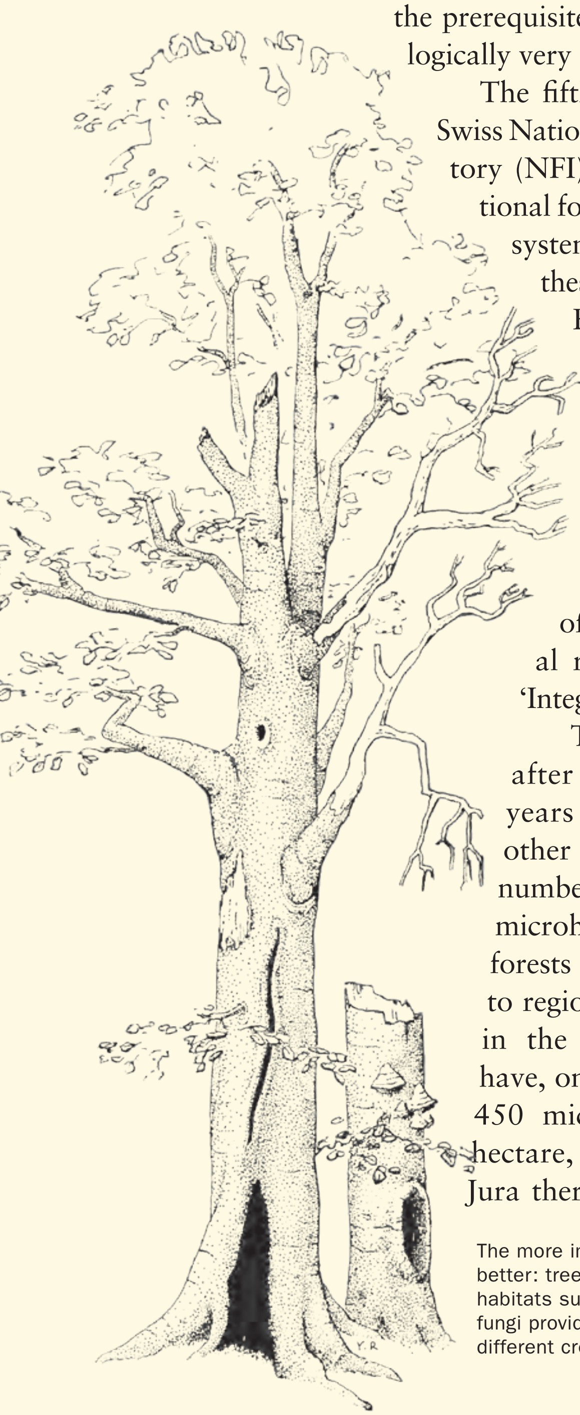
BIODIVERSITY

Small and beautiful: microhabitats on trees increase biodiversity in the forest

Structures on a living tree such as large dead branches, cavities or fungi on the bark are important microhabitats for beetles, spiders or birds. The more trees with such microhabitats there are in a forest, the more valuable it is ecologically. If the forest also contains deadwood, it has the prerequisites for being biologically very diverse.

The fifth survey of the Swiss National Forest Inventory (NFI) is the first national forest inventory to systematically record these microhabitats. For this, it uses the newly introduced European typology of tree-related microhabitats, which was developed as part of the international research project 'Integrate+'.

The evaluations after three survey years show, among other things, that the number of tree-related microhabitats in Swiss forests varies according to region. While forests in the Southern Alps have, on average, about 450 microhabitats per hectare, in the eastern Jura there are only 230.



The more imperfections the better: trees with many microhabitats such as cavities or tree fungi provide shelter for many different creatures.

"Here, as well as on the Central Plateau, there is still room for more diversity," says Meinrad Abegg, a technical staff member of NFI's scientific service. You can also promote biodiversity in managed forests by leaving a selected number of trees with microhabitats. Currently, the most common microhabitats are those covered with lichen and moss, cavities at the base of the trunk and dead branches in the tree crown, while the least common are woodpecker cavities and fungal fruiting bodies.

If tree-related microhabitats are recorded in a standardised way, forests can then be compared internationally. For example, the managed beech forests in Switzerland were compared with the Uholka-Shyrokyj Luh reserve in south-western Ukraine, the largest cohesive virgin beech forest in the world. One result of this comparison is surprising: in both forests the density of tree microhabitats is the same. The types of habitats, however, differ. For example, deep tree cavities filled with organic matter are more common in the primeval beech forest. "Such cavities are very important for rare species such as the hermit beetle, a saproxylic species," says Meinrad. In addition, the primeval beech forest contains more than three times as much deadwood as Swiss beech forests. It's not only the quantity of microhabitats that matters, but also their quality. *(lbo)*

www.wsl.ch/fg-trems

Illustration: Yvonne Rogenmoser

BIODIVERSITY

Artificial intelligence helps to identify plants in the field

Lucienne de Witte is photographing native plants in Switzerland systematically. The resulting images are used to train the algorithm.

When equipped with a smartphone and the appropriate app, anyone can identify plants today. You upload a photo to the app and receive a list of potential species. What makes this possible is the image recognition software in the background. But the identification is not always correct, especially for species that are very similar.

Researchers at WSL are now developing a recognition tool specifically for Swiss plant species that combines images with information about the plants' site conditions. "This combination should significantly improve the accuracy of the identification," says Philipp Brun, who is programming the tool. It is based on artificial neural networks and will complement the Info Flora data centre's 'FlorApp', which has so far been used for reporting on the occurrence of plants but not for identifying them.

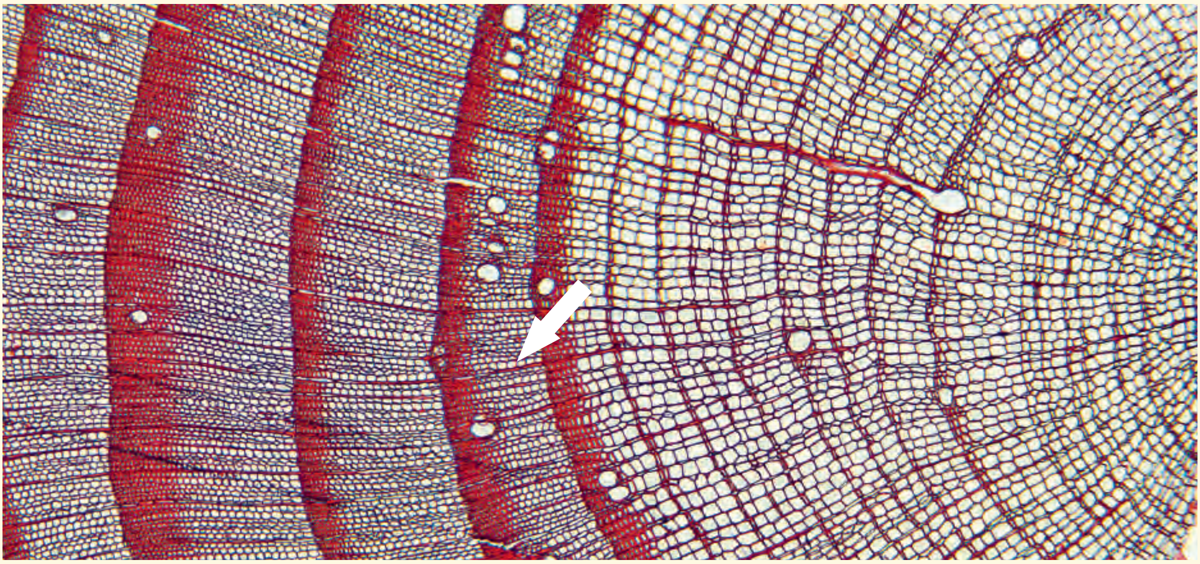
In order for the algorithm to learn to recognise the plants, it has to be trained using as many photos as possible. These are sent in by so-called 'citizen scientists', in this case people who upload their photos to databases and make them available to researchers. Although millions of pictures have now been uploaded, for many of the species that are inconspicuous and difficult to distinguish there are still not enough images. Lucienne de Witte, a plant scientist at WSL, has therefore photographed almost 260 plant species in Switzerland, and produced 18,000 images that she feeds into the computer together with existing images. Other plant scientists will be encouraged to rummage through their private archives to supply further photos. A prototype of the improved 'FlorApp' will be available at the earliest in autumn 2022. *(lbo)*

www.wsl.ch/comeco-en

Photo: Fiona Galliker, WSL

NATURAL HAZARDS

Taking a look at the past: what annual rings reveal about sliding mountains



Under the microscope: when the root was exposed after a crack developed in the ground (arrow), it formed smaller cells.

The mountain near Brienz in the Grisons is on the move. As early as 1881, the British scientific journal 'Nature' reported deep cracks in the ground and noted that the mountain was threatening the village. Since the 2010s, the situation has worsened dramatically, which is why the canton has been closely monitoring all slope movements for several years. But what happened in the years before the intensive monitoring started?

The trees at the edge of the landslide can provide information. When trees start slanting, for example because some of the ground beneath them subsides, they try to straighten up again. When conifers do this, they form so-called compression wood on their undersides, which is anatomically different from normal wood. The compressed wood is therefore easy to detect in the annual rings, and each annual ring can be precisely dated. This enables experts to reconstruct not only when a tree tilted, but also in which direction – and thus indirectly when and how the subsoil moved. The annual rings in the roots provide another source of information as they change their microscopic structure when they are exposed, which makes it possible to tell exactly when a crack in the soil opened.

Valuable information for safety managers

Nadja Studer, a researcher at WSL, and two Bachelor students analysed trees in Brienz and found that the landslide was particularly active from 1850 to 1890 and in the 1950s and 1980s. Holger Gärtner, the project leader at WSL, and Hansueli Bucher from the Technical School Southeast Switzerland (Höhere Fachschule Südostschweiz) maintain: "Our findings on the timing and direction of the movements are new and valuable for those responsible on site who want to understand the complex movements better."

The researchers now want to use the landslide as an open-air labora-

Photo: Holger Gärtner, WSL

tory. “So far, no one knows what exactly happens when a tree forms compression wood,” explains Holger. He and his colleagues have therefore attached motion sensors and two so-called dendrometers to the stems of several trees. The dendrometers measure precisely where and when a stem becomes thicker (see p.36). “This will enable us to watch the Brienz trees grow compression wood.” *(bio)*

When trees become lopsided or roots are exposed, traces are left in the wood, which researchers can then date.

Photo: Christoph Nänni, Geologe Tiefbauamt GR

NATURAL HAZARDS

Public awareness of the need for protection is growing

People's willingness to protect themselves against natural hazards has increased since the Corona pandemic. This was one finding of a recent study by the WSL researchers Elisabeth Maidl and Matthias Buchecker. According to Elisabeth: "Our aim was to find out what influences a person's willingness to take precautions and whether this changes over time." The team therefore surveyed more than 1,500 people living in Switzerland, asking them first in 2015 and then again in 2021.

Sandbags against floods

The participants were asked to answer questions about, among other things, their risk awareness, what precautionary measures they themselves took and how they obtained information. The results of the survey indicate that respondents' risk awareness and their high level of trust in the authorities remained stable, as did the frequency of damaging incidents they experienced personally. In contrast, people's willingness to take active measures – such as buying sandbags as protection against floods – had increased by about ten percent. Why?

According to the 2015 survey, respondents who participate in local community life and engage in discussions are more likely to take precautions. The follow-up survey in 2021 also showed that, as in 2015, people generally want to be involved in public risk management and that this promotes their willingness to prepare themselves and make provisions.

It seems people may be more willing today to take precautions because the Corona pandemic has raised the public's general level of uncertainty. The researchers were able to reach this conclusion because they included specific questions about the pandemic in the second survey. "We were aware that such an event can influence people's attitudes," says Elisabeth. Apparently concern about the pandemic can spread into other areas of life. *(cho)*

SNOW AND ICE

Casting light on the formation of gliding avalanches

So-called gliding avalanches are a great challenge for those responsible for the avalanche services. Such avalanches often occur in early winter when the ground is still warm or when melt- or rain-water penetrates the snowpack. They could happen more frequently with global warming. Gliding avalanches occur when a snowpack that began sliding very slowly downhill on a smooth surface such as a grassy slope suddenly begins to slide rapidly. Predicting this type of avalanche reliably has not yet been possible. From observations of gliding avalanches, we know more water is present between the snow and the ground, but we do not know

Gliding avalanches occur on smooth ground such as grassy slopes.

Photo: Stefan Margreth, SLF

the factors that cause the initially very slow gliding movement to suddenly turn into a rapid slide – i.e. into an avalanche.

Researchers at the WSL Institute for Snow and Avalanche Research SLF are trying to get to the bottom of this problem. They, together with soil experts from ETH Zurich, are therefore systematically investigating – for the first time – the heat and water transport between snow and soil in field studies, laboratory experiments and computer simulations. Their findings suggest that a so-called 'capillary barrier' forms at the interface between the two materials, which are both porous. This barrier prevents water from passing from the fine-pored snow into the soil, which has coarser pores. The water then accumulates at the interface, where it acts like a lubricating film that enables the snow cover to glide over the soil.

Michael Lombardo, a doctoral student at SLF, is investigating these processes in experiments in the lab. His measurements involve filling a cylinder with a layer of sand or natural soil, and then adding snow and installing temperature and humidity sensors at various points. During each experiment, Michael slowly heats the snow until meltwater seeps out and watches to see whether this accumulates at the interface with the soil.

A large-scale research facility yields new insights

Michael is conducting some of his experiments at the SINQ neutron source, a large-scale research facility at the Paul Scherrer Institute PSI.

There he uses so-called 'neutron radiography' or 'neutron imaging' to investigate the distribution of water between snow and soil. In this process, neutrons are 'shone through' the samples. It's rather like taking an X-ray image. With the help of the

The lab set-up the PhD student Michael Lombardo is using to investigate when water collects at the interface between snow and the soil. The snow is above a layer of sand that simulates soil conditions.

neutron particles, you can 'see through' many materials – including soil – almost unimpeded. Water, on the other hand, produces a very strong contrast and is therefore clearly visible. Images are repeatedly taken to see how the distribution of the water changes as the snow melts. Michael emphasises: "One challenge with these neutron experiments is that we are only allotted a few days at a time to take measurements. This means we have to prepare everything very well beforehand because otherwise we would not be able to repeat the experiment until months later." The measurements so far are promising and indicate that the method can be used to track the water transport. The researchers are now planning further experiments to investigate the influence of snow type, soil type and the speed of melting.

They want to use the resulting data to simulate the processes at the snow-soil interface in the computer. This should help forecasters better predict the probability of gliding avalanches occurring based on temperature and snow measurements from weather stations. Michael adds: "We hope that we will be able to provide avalanche warning and local avalanche services with the appropriate tools for this within the next few years." *(mhe)*

Photo: Roman Oester, WSL

Photo: Bruno Augsburger, Zurich

Jacqueline Annen, Birmensdorf

"I like going out for a walk, for example over lunchtime. It helps to clear my head and is good exercise. In summer I go to the forest, but in winter I prefer the fields so that I can get as much light as possible and became pleasantly lost in thought."

CREATING ATTRACTIVE PRODUCTS

Perhaps it's a business card, a WSL report or a practical fact sheet. The layout designer Jacqueline Annen has, for more than thirty years been making the layout and design of such WSL and SLF products attractive. She is a typographer, a profession that has changed a lot over the years. She likes the creativity and the varied challenges her work involves. "Designing a product with text and images and then holding the result – something that lasts – in my hands is very satisfying." *(bki)*

Janine Schweier, Birmensdorf

“I like being in the forest. The peace and quiet there is invigorating and I can recharge my batteries. As a habitat it fascinates me. Forests provide so many ecosystem services including not only timber, but also clean water and protection against natural hazards.”

VIRTUAL FORESTS WITH PRACTICAL APPLICATIONS

Janine Schweier is a forest scientist and head of the research group ‘Sustainable Forestry’. With her team, she is supporting forest enterprises in finding ways to use the forest that make economic and ecological sense. They have therefore developed IT tools such as the ‘virtual forest’ that enterprises can use to plan and visualise interventions. “It’s very gratifying if our research results and tools contribute to making forest management more sustainable.” *(lbo)*

Photo: Bruno Augsburger, Zurich

OUTLOOK DIAGONAL NO. 2, 2022

How can we shape our future sustainably? To ensure that development worldwide is ecologically, socially and economically sustainable, the United Nations has formulated seventeen goals – the Sustainable Development Goals (SDGs). At WSL, researchers are also working to promote these goals by, for example, studying spatial development, the use of forests or the effects of the energy transition. In the next Diagonal, you will find out more about WSL's contribution to sustainable development.

Graphique: www.un.org/sustainabledevelopment. The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its officials or Member States

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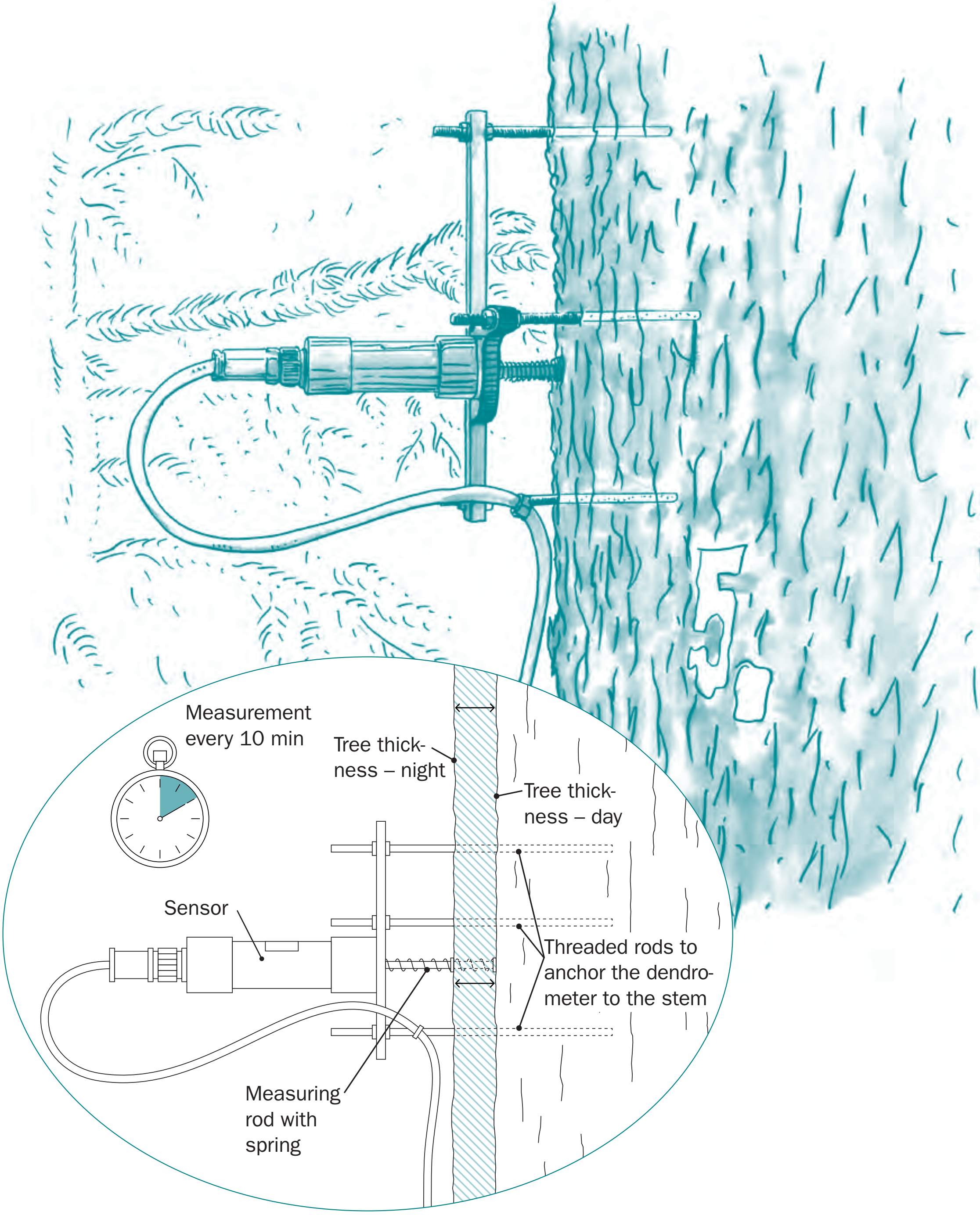
PEOPLE

The Diagonal editorial team, from left to right, top row: Stephanie Kusma, Beate Kittl; bottom row: Birgit Ottmer, Sandra Gurzeler, Claudia Hoffmann, Lisa Bose

Photo: Gottardo Pestalozzi, WSL

THE POINT DENDROMETER



The point dendrometer is a useful tool for finding out how dry periods affect forests. It measures a tree's growth and water deficit by recording tiny fluctuations in the stem's thickness. During the day, the stem shrinks because more water evaporates through the stomata in the leaves than is absorbed by the roots. At night, these openings are closed and the stem expands again. In addition, the stem becomes thicker during the growing season due to the newly formed wood and bark cells. The researchers from TreeNet (treenet.info), a research network under WSL management, have installed over 350 point dendrometers in the Swiss forest. The fine temporal resolution of the resulting data is unique.

Video at:
www.wsl.ch/object

Illustration: Raffinerie; Cover: Beat Wermelinger, WSL

Agriculture: Can it be intensified sustainably? p. 22

Microhabitats: Tree-related microhabitats promote biodiversity in the forest, p. 26

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RESEARCH FOR PEOPLE AND THE ENVIRONMENT

The Swiss Federal Institute for Forest, Snow and Landscape Research WSL conducts research into changes in the terrestrial environment, as well as into the use and protection of natural spaces and cultural landscapes. It monitors the condition and development of the forests, landscapes, biodiversity, natural hazards, and snow and ice, and develops sustainable solutions for problems that are relevant to society – together with its partners from science and society. WSL plays a leading international role in these research areas, providing the basis for sustainable environmental policy in Switzerland. WSL employs more than 500 people in Birmensdorf, Cadenazzo, Lausanne, Sion and Davos (WSL Institute for Snow and Avalanche Research SLF). It is a Swiss federal research centre and part of the ETH Domain. You can find WSL’s annual report online at: www.wsl.ch/annualreport.

WSL

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