WSL MAGAZINE

DIAGONAL

FOCUS

HOT!

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Swiss Federal Institute for Forest, Snow and Landscape Research WSL

EDITORIAL

Dear Reader
This summer really made us sweat. It was the third warmest summer in Switzerland since measurements began in 1864. Globally, it was even the hottest since 1940, with July as the warmest month worldwide and August the second warmest. But it wasn't just us humans who were hot. Trees and glaciers also sweated – with fatal consequences for some, as several articles in this issue show. But even what – for us – may not feel at all hot can have an impact. A little extra warmth for plants in the high mountains and in the tundra may stimulate them to grow and some trees to sprout new shoots. This DIAGONAL examines these as well as other issues, such as why snow is actually a high-temperature material. And we also introduce you, dear readers, to the hottest place at WSL.
On that note, I wish you a "hot" read now during the cooler season of the year!

Christoph Hegg
Acting Director WSL

FOCUS

HOT!

KEY TOPICS

PORTRAITS

Photo: Matthias Huss, WSL

ADAPTING TO CLIMATE CHANGE

We need to transform our cities to ensure they remain inhabitable despite the effects of climate change. Researchers at WSL are working on solutions – and investigating why the existing know-how is rarely implemented.

Living with heat in cities

Unsealed surfaces store less heat than asphalted areas. They also allow rainwater to seep into the ground over a large area during heavy rainfall, which is then available for the vegetation that helps to cool the city.

The Idaplatz in Zurich is a positive example: the numerous trees there provide shade and cooling through evaporation. No wonder, then, that the square is a popular meeting place even on hot summer days.

The water in the fountain cools the surroundings. Having direct contact with water also increases the well-being of humans and animals, especially if the water is drinkable.

Idaplatz, Zurich

Photo: Tamara Baumann, WSL

The heat is oppressive. The air stands still. People sweat profusely. In summer, it can get unbearably hot in Switzerland's larger cities. In the city centres where concrete, glass and asphalt predominate, temperatures can be as high as 40 degrees Celsius – with negative consequences for public health. During the exceptional summer of 2003, a total of 1'402 deaths due to the heat were recorded in Switzerland. They accounted for 5.6 percent of the total mortality between May and September that year.

"Heatwaves are one of several impacts climate change is having. Another is heavy precipitation," says Marco Pütz, a geographer at WSL who studies, among other things, strategies for adapting to climate change. He and his team have found that public awareness of the problem is growing. In 2009, the topic of climate adaptation was, according to one study, not yet a priority in the planning of Swiss cities. Ten years later, responses to a survey conducted in 2019 as part of a master's thesis indicated that urban planners were at least aware of the problem. But measures that could diminish the heat are still too seldom implemented.

Building in a changing climate

No legal mandates exist yet in Switzerland that oblige cantons and municipalities to adopt measures to adapt to climate change. According to Marco, such mandates would make implementation easier. "It would also," he recommends, "be a good idea to ensure that adapting construction methods to climate change is made part of the compulsory training of architects, civil engineers and urban planners."

“We already know a great deal. For example, we know cities should contain more areas with water and shaded green spaces and a higher proportion of unsealed surfaces,” says Marco. “One topic we are exploring is why this know-how is implemented so hesitantly. We also want to find out which decision-making processes best promote implementation.”

Dominik Braunschweiger, a doctoral student of Marco, identified one problem in his thesis: both “heat” and “climate adaptation” are cross-sectoral topics affecting sectors for which several different authorities are jointly responsible. The issues should really be addressed by the federal government, cantons and municipalities in cooperation. The Federal Council’s Strategy for Adaptation to Climate Change in Switzerland makes this clear and sets the framework for coordinating the approaches of the different federal agencies. The Action Plan 2020 to 2025, which is coordinated by the Federal Office for the Environment, includes measures involving the sectors: dealing with natural hazards, forestry and agriculture, energy, human and animal health and spatial development at the federal level.

Action required because cooling is insufficient

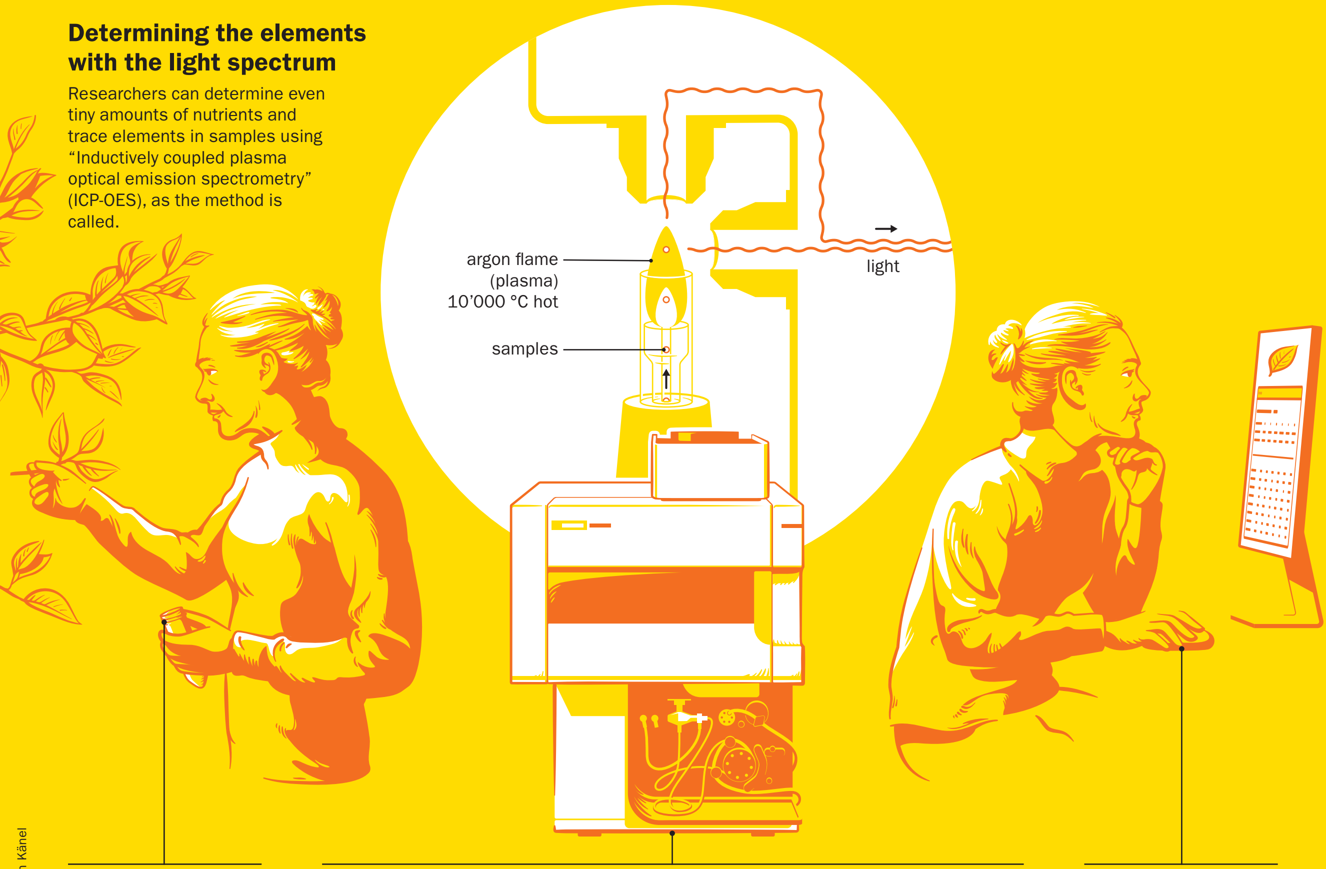
Until legal requirements exist or the cities themselves recognise the need to act, federal initiatives, such as the pilot programme “Adaptation to Climate Change”, can help. The programme, which ended its second phase in 2022, has provided the cantons, regions, cities and municipalities with technical and financial support and helped to raise awareness about climate issues including heat among politicians and the public.

Even without official guidelines, several municipalities have already started taking action because the effects of climate change, especially heat, are becoming increasingly noticeable. Some cities such as Bern, for example, have produced climate maps as a new basis for planning. In 2017, the city of Zurich introduced a special Heat Mitigation Plan. Its goal is to reduce the negative effects of heat on the urban population and to improve the urban microclimate, which is also urgently needed. According to the climate scenarios of the National Centre for Climate Services NCCS, the federal government’s virtual coordination centre for climate services, Zurich’s population will have to endure twice as many very hot days above 30 degrees Celsius in 2035 as in 1995. *(lbo)*

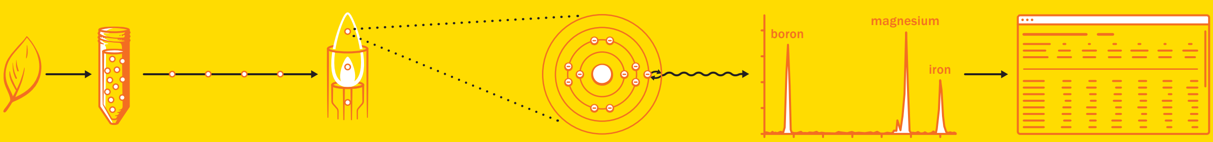
INFOGRAPHIC **The hottest place at WSL!** 10’000 degrees Celsius is the temperature the argon flame reaches inside the atomic emission spectrometer. It’s used to analyse the chemical make-up of samples.

Determining the elements with the light spectrum

Researchers can determine even tiny amounts of nutrients and trace elements in samples using “Inductively coupled plasma optical emission spectrometry” (ICP-OES), as the method is called.



In the field · **In the lab** · **At the computer**



Samples
Samples that researchers have collected of, among other things, soil water or leaves, are prepared by a lab technician for analysis in the spectrometer.

Argon flame
A generator heats the argon gas to 10’000 °C, thereby creating a plasma. The great heat of the plasma breaks down the molecules of the sample into individual atoms.

Atoms
The electrons of the atoms reach an excited, higher-energy state. When they drop back into a lower-energy state, light is emitted.

Light spectrum
A photo-cell measures the wavelength and intensity of the light. These values indicate what the individual elements are and in what quantity.

Evaluation
Special software lists the types and quantities of the elements in a table. The researchers then evaluate the results of the analysis.

What is the method used for at WSL?

Soil research
Researchers at WSL are currently repeating the forest soil inventory carried out in 1993. They record the nutrients and pollutants contained in the soil samples they collect.

Forest ecosystem research
WSL monitors the health of the forest on behalf of the Swiss government on 19 sites throughout Switzerland, analysing samples of leaves, soil and soil water.

Forests and drought
To find out how trees adapt to drought, forest researchers use the spectrometer to measure the plant nutrients in, for example, pine needles.

Infographic: Michael Stünzi and Daniel Röttele, infografik.ch; data and text: Beate Kittl and Karin von Känel

A piece of glacier in the freezer.

Ice and heat do not get along well. This year the temperature records have again reached new highs. What does this mean for the glaciers – in Switzerland and worldwide? The findings of the researchers at WSL investigating this are alarming.

"I simply wanted a bit of it to continue to exist," says Matthias Huss. The glaciologist from WSL and ETH Zurich is talking about the Pizol Glacier, or what is left of it: a few hundred square metres of ice that no longer moves. Experts call such remnants of a glacier that no longer exists "dead ice". Matthias paid another visit to the remnants of the Pizol Glacier in July and took a chunk with him. He keeps it in his freezer. The trip was private. The head of the Swiss glacier measurement network GLAMOS has not had to go there for professional reasons since 2020. "There's nothing left to measure there," he says.

This statement will apply to at least half of all glaciers worldwide by 2100. Most of them are currently still small ice streams less than one square kilometre in area – as the Pizol Glacier was. According to the scenario modelled by an international team of researchers, including Matthias and his WSL and ETH colleague Daniel Farinotti, Switzerland will have lost about seventy percent of its glacier mass by the end of the century – and this is for the best-case scenario in which it has been possible to limit global warming to 1.5 degrees Celsius.

If the glaciers melt, this will have far-reaching consequences – for the supply of drinking water, irrigation for gardens and agriculture, energy production and waterways. In addition, sea levels will rise and, without countermeas-

Researchers drag a Ground Penetrating Radar (GPR) over the Trent glacier to measure the thickness of the ice.

Photo: Raphael Moser, WSL

ures, large areas of land will be flooded. The risk of natural hazards, such as rockfalls and glacial lake outbursts, will also change.

Enough water for Lake Constance and Lake Neuchâtel

Switzerland has already lost unimaginable amounts of glacial ice – between the 1930s and 2016, the volume of its glaciers halved. Around 62 cubic kilometres of ice melted during this time – resulting in enough water to fill both Lake Constance and Lake Neuchâtel. The researchers reconstructed, in a recent study, the former earlier volume of the glaciers on the basis of more than 21'000 historical photos.

Between 2016 and 2022 alone, Swiss glaciers lost another approximately nine cubic kilometres of ice. The worst was in 2022 when they lost six percent of their volume. Two percent was already considered extreme. Little snow had fallen in the winter before. "Snow cover protects the glacier ice," explains Matthias, the glacier researcher. This is because it reflects the sun's rays. Without this protective layer, the darker ice absorbs the radiation, heats up and melts. In 2022, this was already happening in May, one to two months earlier than usual, because of the low amounts of snow in the winter.

In addition, heat waves occurred that led to extreme melting events. The researchers were able to detect this with the help of a new method they developed that allows them to calculate the daily ice loss. Until now, this was only possible over a longer period. They identified 23 days on which significantly more ice melted than usual. Many of these coincided with heat waves, i.e. three consecutive days with maximum temperatures of over 30 degrees in the lowlands. A third of the total annual loss in 2022 was due to these heat waves. "Those that happened at the beginning and end of the season were particularly drastic," Matthias says. "In August, considerable melting occurs most years and 2022 was less exceptional." This year – 2023 – Swiss glaciers have lost four percent of their volume. "By mid-July, the point had already been reached where the snow accumulated during winter had been depleted and the balance became negative. If the glaciers were healthy, this point would not be reached until the end of September." This means that, in just the last two years, as much glacier ice has disappeared as in the thirty years between 1960 and 1990.

If it continues like this, it looks bad for the glaciers. According to the researchers' models, if global temperatures rise by three degrees instead of 1.5 degrees, barely twenty percent of the world's glaciers will still exist in 2100. These will be concentrated in the high mountains of Asia, the far north and Antarctic regions. "Switzerland would then be as good as ice-free," says Daniel. *(kus)*

Double page p. 8/9: Dea Andreea, Unsplash

Although snow feels cold to us, it's actually a high-temperature material that is always just about to melt. That's why building with snow is only possible at certain temperatures. The warmer the snow, the closer it is to its melting point. It is then easier to shape and more likely to stick together to make a solid snowball. Sometimes even small fluctuations in temperature can determine success or failure.

What helps is to roll the ball slowly through the snow, letting it rest for a few seconds from time to time to give the molecules in the snow a chance to stick together, i.e. to sinter well. The process is the same after an avalanche: when the snow mass stops moving, the snow becomes incredibly hard within a short time. That is why it is difficult for people buried in an avalanche to free themselves.

Building a snowman

FOREST **“Sweating” forests.** When the atmosphere heats up, forest trees lose more water, and increasing numbers die. Researchers at WSL are investigating the phenomenon and seeking tree species that can sustain higher temperatures.

If it remains hot for a long time, it is not only people and animals that suffer. Trees can literally “sweat” themselves to death. As the air gets warmer, they can store more moisture, and the difference between the humidity inside and outside the leaves increases. This is dangerous because the air then “pulls” water out of trees more strongly. If the pull on a plant’s hydraulic system becomes too great, parts of it may collapse – with fatal consequences for the plant. To prevent this from happening during heatwaves, trees close their stomata, as the pores in their leaves through which water vapour and other gases come and go are called.

For more on the topic, see the video: “Pressured to transpire” *youtu.be/9sKYRgilA1I*

The “water hunger” of the air, which is known as the Vapour Pressure Deficit or VPD (see inset), has, in many places in the world, been rising for several years due to climate change. In Switzerland, too, it is increasingly limiting tree growth, as the model calculations of Volodymyr Trotsiuk, a data scientist, and his colleagues at WSL have shown. The reason is that trees can no longer carry out photosynthesis when the stomata are closed.

Heat death despite wet roots

Increasing VPD accelerates tree death even when soils are wet, as Charlotte Grossiord, Joint Professor at WSL and EPFL, has found. “When air dryness occurs together with wet soils, it can lead to the same damage in plants as during dry periods, especially in more susceptible species,” she explains. This finding is new – until now, soil dryness was considered in forest research to be the biggest risk factor affecting tree mortality.

Charlotte has been studying how the increasing VPD affects forest trees for several years. In an experiment at ETH Zurich, she exposed beech and oak trees in closed chambers with controlled climate to temperatures of up to 30 degrees Celsius and high VPD, i.e. very dry air. Although the soil was irrigated, the pull on the plants’ water hydraulic systems became too great, and they collapsed. “This explains why trees can die in the heat even if their roots are in water,” she says. “And it’s very worrying because – from a purely physical perspective – the VPD will increase with global warming.” Until a few years ago,

The “water hunger” of the air

The vapour pressure deficit (VPD, given in kilopascals; kPa) is the difference between the moisture in the air and the maximum amount of moisture that the air can absorb. It is a measure of the air's “water hunger”. Since it influences the release of water vapour from plants (transpiration), and consequently the supply of water and nutrients, it is an important factor influencing forest growth and tree mortality. VPD has been increasing worldwide since the 1990s due to rising temperatures.

Janisse Deluigi, a PhD student at WSL, measures the photosynthesis of beech and oak saplings in the model ecosystem facility at WSL. The trees are exposed to varying levels of heat and drought.

Photo: Tamara Baumann, WSL

oaks and beeches in particular were thought to be drought-resistant enough to cope with the anticipated temperatures in Central Europe.

The plant physiologist's team is now continuing this research in WSL's experimental garden using glass climate chambers that are open at the top. The chambers are heated and the irrigation controlled, which should reveal the respective influences of heat and drought. Last summer, Charlotte Grossiord and Marcus Schaub, an ecophysiologist at WSL, and their teams also began setting up a unique experiment in Pfynwald, where WSL is carrying out a long-term irrigation experiment in a drought-exposed, natural pine forest stand in Canton Valais, to find out more about how different VPDs affect trees.

For more information on WSL's experiments in Pfynwald, see: *wsl.ch/pfynwald-en*

WSL has been irrigating parts of this very dry forest for twenty years with sprinklers, doubling the natural rainfall. In some parts of the forest, the researchers have installed a sophisticated system of misting nozzles around the tops of the trees that reduce the VPD by increasing the humidity. They have also covered those parts of the understorey below the mist to intercept natural precipitation. This enables them to disentangle the effects of dry air from those of dry soil.

"This is the first time worldwide that VPD and soil drought have been manipulated together in a mature natural stand," says Marcus, the project leader. The long-term goal is to learn more about the processes that explain the growth and mortality of tree species under varying environmental conditions. The study focuses on several levels: the plant cell and tissue, the individual tree and the whole forest stand. "Once we know when it becomes too dry for a particular species, we can produce better models of forest growth and mortality under different climate scenarios."

Warm winters, late frosts

Too much heat is not only a summer phenomenon. Mild winters also pose a risk: if trees start sprouting early in spring when temperatures are high, their hydraulic systems are more likely to experience frost damage. Tree species regulate leaf sprouting in spring differently and are therefore not equally at risk. Beech trees mainly orient themselves to the length of the day and react less to warm spring temperatures. Oaks, however, start sprouting as soon as it gets warmer, as Charlotte's experiments showed. For them, a late frost can be fatal. But oaks also have a head start in spring.

In the forest, survival is all that matters. What is decisive is which plants grow faster, as well as which win the competition for light and nutrients, and which quickly outgrow the threat of browsing herbivorous ungulates. How does the balance shift when hot, dry years alternate with cool, wet years? "This is crucial for the regrowth of young trees, which form the forest of the future," says Barbara Moser, a biologist at WSL. She is investigating which tree species can cope best with warmer winters, hot-dry summer months and late frosts. "We are simulating what we assume will be the prevailing climate on the Swiss Plateau in thirty to fifty years' time," she says. "But cold winters and late frosts will still happen – and species from the Mediterranean region will tolerate them less well."

Barbara's team has set up six polytunnels at three separate sites, each the size of a tennis court. The tunnels are like those commonly used as temporary greenhouses in agriculture. Inside and in the surrounding areas, she has planted the three native tree species, beech, sessile oak and silver fir, as well as three from hotter and drier regions such as North Africa, namely Douglas fir, Atlas cedar and Turkey oak. They are now growing under either currently prevailing or predicted environmental conditions. Foresters depend on such experiments to help them plan, as quickly as possible, forests that will not sweat themselves to death in fifty years. *(bki)*

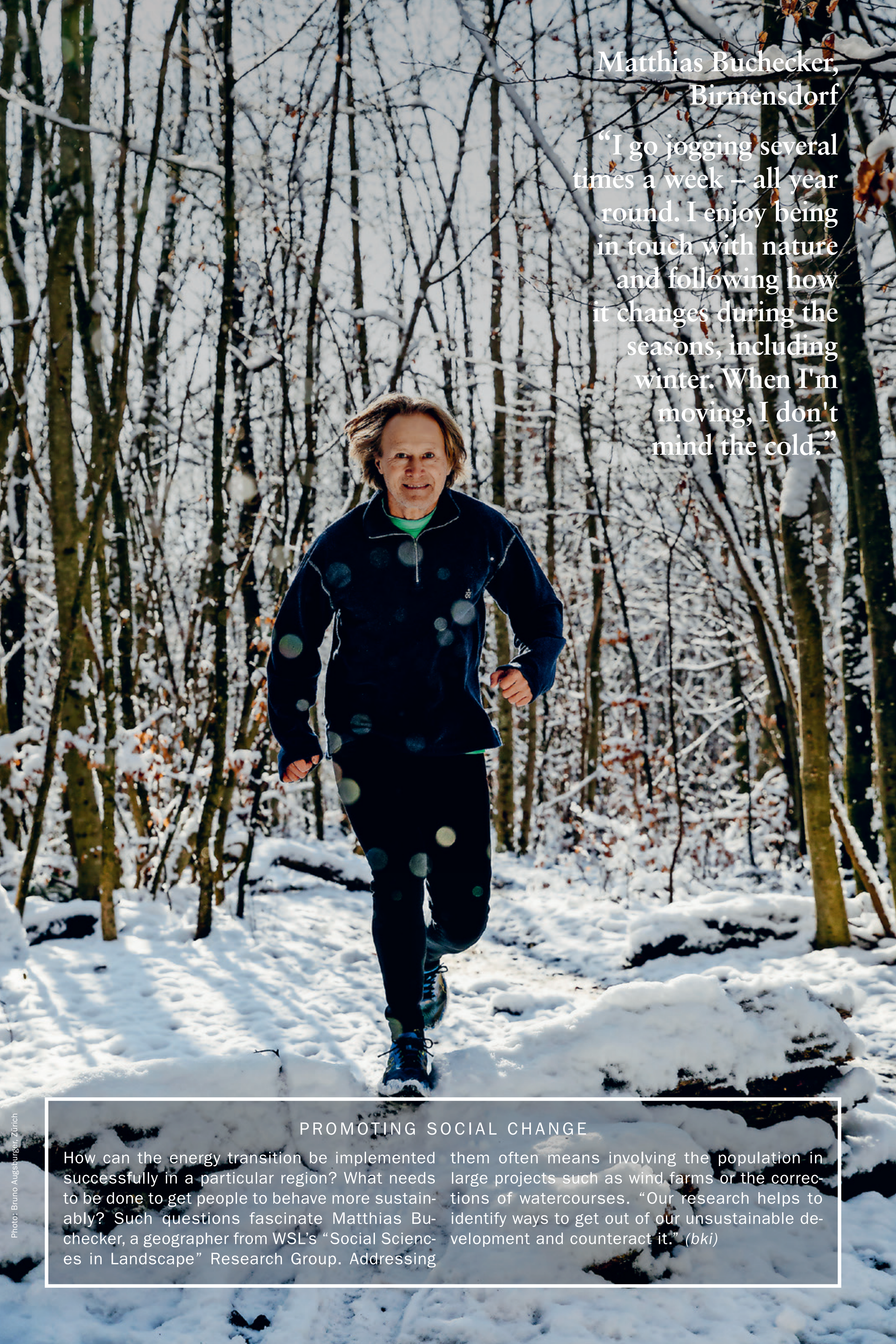


Photo: Bruno Augsburger, Zürich

Matthias Buchecker, Birmensdorf

"I go jogging several times a week – all year round. I enjoy being in touch with nature and following how it changes during the seasons, including winter. When I'm moving, I don't mind the cold."

PROMOTING SOCIAL CHANGE

How can the energy transition be implemented successfully in a particular region? What needs to be done to get people to behave more sustainably? Such questions fascinate Matthias Buchecker, a geographer from WSL's "Social Sciences in Landscape" Research Group. Addressing them often means involving the population in large projects such as wind farms or the corrections of watercourses. "Our research helps to identify ways to get out of our unsustainable development and counteract it." *(bki)*

Photo: Stephanie Kusma, WSL

PLANTS AND CLIMATE CHANGE

Greener, taller, denser.

For thirty years, researchers in the International Tundra Experiment have been studying how plants in the high mountains above the treeline and in cold regions react to experimentally increased temperatures. WSL has been involved from the very beginning.

The narrow mountain path winds up from Mulegns into Val Bercla (Surses, Canton Grisons). It is above the treeline and there is snow on a nearby ridge. Taking along the UV protection and headgear was a good idea as the July sun is burning my face even though the air is still cool in the early morning. After an hour and a half of climbing, Christian Rixen, a plant ecologist at SLF, points towards a small hill in front of us on the right of the path. "We're almost there." Mauro Vareni, who is doing his civilian service at SLF, and Melissa Gerwin, a visiting PhD student from the University of Tasmania in Australia, accompany the researcher when he turns off the path shortly afterwards.

One last gentle incline and then they see them: nine hexagonal plastic chambers, each about a metre diagonally across and open at the top. It looks like a settlement in a science fiction film, only smaller. The neon-green mesh of an electric pasture fence surrounds the structure, neatly spread out on the ground. Christian takes off his hat and wipes his forehead. "That looks good," he comments with satisfaction.

The experimental area is part of the International Tundra Experiment (ITEX). The aim is to find out how vegetation that has adapted to the cold in the tundra and the Alps is reacting to the increasing temperatures. The plastic chambers act like small greenhouses. Inside them it's one-to-three degrees warmer than outside. This simulates the higher temperatures brought about by climate change.

The three of them unload the material they have lugged up here over a distance of five kilometres and six hundred metres in altitude. Mauro unpacks a battery with a solar panel to supply the pasture fence with electricity. In the meantime, clouds have gathered and the wind has picked up. It's time to get our wind-jackets out of our backpacks. Mauro puts on a black woolly hat. He begins to put up the old green fence. Christian explains the precautionary measure: "Cattle will soon be grazing here again, and we don't want them in the experiment!"

Spread over five continents

ITEX comprises more than forty research sites in North and South America, Europe, Asia and Antarctica. All the research sites have identical thermal chambers, and the researchers there record their data in the same way. "This means," Christian says: "that not only do all the researchers have more data than they could possibly obtain on their own, but it also enables them to carry out completely different analyses." For example, one effect is that when it gets warmer, more shrubs grow. This effect is particularly evident in places where more water is available – a finding which would not have been possible without enough data from both wet and dry sites. The first ITEX experimental site was created in the Alexandra Fjord on Ellesmere Island in the Canadian Arctic. Felix Gugerli, a researcher at WSL, set up the Swiss trial there in 1994, and researchers from SLF have been in charge of the site since 2009.

Melissa repositions one of the heat chambers. Inside it, you can clearly see where the mini-greenhouse was before as one corner of the ground is bare. In front of it, low green cushion plants and grasses are growing along a strip a hand-breadth wide with a sharp border. Outside the chamber, small pieces of wood mark where the plastic walls should be. When the chamber is back in the right place, Melissa secures it to the ground with tent ropes and pegs.

"The plants up here are living under extreme conditions with, for example, long and cold snow cover and high UV radiation," says Christian. "They need these conditions, or can, at least, cope well with them." He carefully raises one side of a plant a little. It is a prostrate shrub with roundish leaves and barely two centimetres high. "This is a herbaceous willow, which suggests it belongs to a tree genus. Carl von Linné called it the smallest tree in the world. But despite its name, it is not, in fact, a tree at all." The small plants are growing all over the experimental area, as are pink-flowered moss campion and pale blue Alpine forget-me-nots. Melissa is delighted: "In Australia, forget-me-nots are invasive. It's nice to just admire their beauty for a change, because they belong here."

The most important factor is the temperature

"Watch out! Don't step inside it," Christian shouts. Next to each plastic hexagon, one square metre of floor is marked out with white strings. "These are the control areas," he explains. There the naturally occurring flora is the same as that growing in the mini-greenhouses, but inside the chambers the temperatures are lower. By comparing the vegetation inside and outside the chambers, the researchers can find out more about how the flora in cold areas is likely to alter with climate change.

The floor inside the mini greenhouses looks greener than the rest of the areas. "That makes sense," Christian says. "Our data shows that the plants grow better with just a little more warmth." They have more leaves and grow taller and more densely. The fact that it is less windy and more humid inside the chambers than outdoors does not seem to play a role. "The experiment has been running for so long that we can check our experimental results," he explains. "It is now warmer in ambient conditions outside the chambers than it used to be inside them." Time has confirmed the earlier results: temperature is the most important factor for the plants in the chambers.

More competitive species have spread due to the additional warmth. However, most of the small Alpine specialists are still present. "These processes take place very slowly," Christian says. "New and larger plant species, for example, first have to make their way up to the experimental plots. If a plant species doesn't occur nearby, its seeds also won't be able to get inside the chambers."

Changes in the vegetation of cold regions have far-reaching consequences. They influence, for example, snow cover by causing snow to accumulate in

Securing the plastic panels of the heat chambers with tent pegs and ropes.

front of taller plants, as well as how much carbon the soil stores. This, in turn, affects both the vegetation growth and the climate.

After a good two hours, everything has been set up, including last year's fence. Time for a lunch break. The three of them share cheese, sausage and quince bread. Mauro scans a steep mountain slope about a kilometre away from the experimental site through his binoculars. "Look! I can see ibex!" More than twenty bucks, does and kids are grazing or resting on the slope.

The sun has disappeared behind the clouds. It has cooled down further. The three pack up their picnic. They start unrolling the second new fence they brought with them and fixing it around the old one. The terrain is rocky, the layer of earth often thin. In other places, deep gullies make it difficult to fence off the area securely. It takes them time to get everything ready so that Mauro can connect the battery. Everyone listens. The fence starts ticking quietly. For now, at least, it should keep out the cattle.

It begins to drizzle. Christian and Mauro quickly stuff the surplus ropes and pegs under the rock in the middle of the site and cover them with stone slabs. Then the three of them set off on their way back. It takes only a few steps for them to get out of sight of the test site. But the sun is back. Right next to the hiking trail is a meadow full of orchids. In the morning they had no time or energy to admire them, but now they can take photos. Nevertheless, it takes them much less time to descend than it did for them to get there. The three of them arrive back in the valley in the late afternoon. The return trip to Davos takes a good hour. Then the field day is over – until the next visit. "We'll need to check the fence again before too long," Christian says. *(kus)*

For further information, see: *slf.ch/itex-en*

Photo: Stephanie Kusma, WSL

ONE-TWO **"People are the main cause of forest fires."** DIAGONAL joined the WSL researcher Marco Conedera and Aron Ghiringhelli, the person in charge of forest-fire issues at Ticino's Forest Service, to talk about forest fires.

Aron Ghiringhelli is in charge of forest fire issues at the Ticino Forest Service and is a member of the mountain fire brigade, a specially trained fire-fighting unit.

Marco Conedera is a forest engineer at WSL's location in Cadenazzo (Canton Ticino). His research includes the history and ecology of forest fires.

What is a forest fire? How many trees have to burn for it to count as a forest fire?

MC: We don't normally distinguish between a tree and a forest, but define forest fires as fires affecting forest areas that get out of control. It may be just one tree that gets struck by lightning, but it may also involve an entire stand.

AG: And trees don't always burn down completely either. There are three main types of fires: some occur in the crowns of trees, others burn the litter layer close to the ground, while the third type burns the humus and roots in the topsoil.

Do fires also ignite spontaneously when it is very dry?

AG: No, that does not happen in Switzerland. Here we have just one natural cause, namely lightning, which is only a summer phenomenon.

MC: Exactly. It is almost always people. We humans are the main cause of forest fires. It could be that a fire on the ground doesn't get properly extinguished. Or – (he stops to listen to a shrill sound from further down the valley) – what we're hearing now. When using a machine like that, in this case a strimmer, sparks may fly. If there is already fire danger in the forest, a single spark can be enough to start a fire. It is really important to raise public awareness and inform not just the locals, but also tourists.

Has the number of forest fires occurring in Switzerland changed much over the years?

MC: We don't, unfortunately, have any comprehensive historical data for the whole of Switzerland, but we do have data for the Alps, Canton Valais and the Grisons – as well as for Ticino. Here we have statistics covering the past 100 years which show that, after the Second World War, between 1955 and about 1980, both the number and extent of forest fires increased markedly. During this time, many traditional farming practices were abandoned. And people then were not as aware of the dangers as they are today. They were often careless with fire – which is how many fires started. It was not until the 1990s that we began, at last, to get the number of forest fires under control by, for example, banning the burning of garden waste outdoors.

Is climate change increasing the danger?

MC: It certainly plays a role, but exactly what role, we will only be able to say in coming years. But clearly, summer temperatures will rise, and that means the likelihood

Photos: Jochen Betttzieche, SLF

of forest fires occurring will be greater. We are already seeing more thunderstorms in the summer during droughts, and they don't bring much rain. As a result, lightning is more likely to start a fire. But the fire itself is not the only danger that the burning of a forest poses.

What else then?

MC: Forests often have a protective function, especially in the mountains. They help to prevent avalanches, rockfalls and debris flows from reaching populated areas. When such a protection forest burns down, the community below it remains exposed to these natural hazards for years, if not decades. This is why we are, for example, producing hazard and risk maps.

But surely there are other things too?

MC: Of course. We do a lot of research on forest fires and cover the whole spectrum, including prevention, such as determining the daily risk of forest fires, as well as their ecological consequences. We are investigating, among other things, how well particular tree species burn and how they react after a fire.

We are now standing here above Biasca (Canton Ticino) in the forest on Motto Bruciato, the 'Burnt Hill'. How threatened is it?

MC: It is quite at risk, as the name already suggests. There are more fires here and human activities take place close by. Further down the slope we saw people working. It is also very exposed, as we noticed coming up here. When the sun is shining, it dries up here much more

Flames flickering in the night. Forest fires like this one in Gambarogno are spectacular to watch, but may have serious consequences.

Photo: Nicola Bomio-Pacciorini/TI

quickly than anywhere else. The north foehn wind, which can fan the flames, is also frequent here. To add fuel to the fire, many of the trees here are chestnuts, whose litter catches fire quickly. So we certainly have all the components that make the likelihood of forest fires greater here than in other areas.

A question for the practitioner: in what ways can scientific research help the fire service and forestry?

AG: The results provide us with a basis for deciding on our strategy for tackling several issues. In prevention, for example, we identify those days that are likely to be the most dangerous in a particular period. We also need to know which areas are most at risk in order to prepare for possible action, as well as where to install the necessary fire-fighting infrastructure, such as reservoirs for the helicopters spraying water. If a forest burns despite prevention efforts, input from research helps us to decide on the right measures. We can then try to concentrate on the areas where the forest provides protection.

Where is more research needed?

AG: WSL's results are a great help. Nevertheless, there are certainly many areas where more information would be useful but where research is also already being done. Among other things, it's about improving the resilience of forests against fire. Ensuring the danger remains small is an interesting task that requires optimisation. Warning signs are another example. If they are in a tourist region, it is not enough to use the official local language. The signs also need to be in the languages of the most common regions or countries of origin of the visitors.

But you could also transform the forest so that it doesn't burn so easily.

AG: That's not really feasible. For one it is too expensive and the chances of a fire actually occurring are too small. And if it does burn, it will burn even if it has been transformed. There are no resistant species, but only trees that burn better or less well. I think it is very important to keep in mind that our goal is not to prevent all fires, but to ensure the fires remain small and don't spread. This is because if the burnt area is large, another danger arises: when it rains, there's more likely to be erosion. The rainwater then washes the soil down into the valley, which can lead to rockfall and debris flows. If only a small area burns, the risk is not so great. This is why we have to try to keep the fires as small as possible.

What challenges does a forest fire pose for the fire brigade?

AG: Dealing with a forest fire, especially in the mountains, requires special know-how. Here in Canton Ticino we have our own specialised mountain fire brigades. I am also a member of such a brigade and one of the three hundred people who are trained for such events. We are different from a conventional fire brigade, which we, as a specialized unit, support. We really have to be able to work together and coordinate with the other fire brigades and services involved. No fire brigade has the capacity to put out a forest fire on its own.

How should people behave if they spot a fire in the forest?

MC: Well, I would say first go to a safe place and then call the fire brigade.

AG: Exactly. Trying to extinguish it could be dangerous. When a fire really gets out of control, you won't be able to stop it using ordinary means. *(job)*

"Our goal is not to prevent all fires, but to ensure that fires remain small."

Photo: Bruno Augsburger, Zürich

Sophie Stroheker, Birmensdorf

"When I'm teaching a course in the fitness centre, I am fully present in the "here" and "now". There's then no room in my head for anything else apart from the next exercise, and I train much more intensively than when I'm on my own. I enjoy encouraging people to test their limits."

TRACKING DOWN TREE DISEASES

Sophie Stroheker is a forest pathologist. She diagnoses tree diseases for "Swiss Forest Protection", a competence centre at WSL that specialises in forest protection issues. Not only does she work closely with foresters and advise them, but she also manages the database of recorded diseases and pests. She enjoys having contact with practitioners and working outdoors in the forest. "But I also like doing detective work in the lab. I often have to be quite persistent when trying to find out why a tree has a particular disease." *(lhu)*

FOREST

The Douglas firs in our forests are rarely used by forest insects

Martin Gossner checks a device in a plastic pipe on the grounds of WSL. The so-called emergence trap catches insects as they hatch.

It's summer 2023 in the grounds of WSL in Birmensdorf. Hidden behind piles of compost is a big stack of large orange plastic sewer pipes a good ten metres long and about two metres high. The lids that close the ends of the pipes each have a small window cut into it that is covered with a net and an opening that leads into a bottle filled with seventy-percent ethanol. The liquid in many of the bottles is clear, but in others there are small – or sometimes large – creepy-crawlies swimming around.

The bottles are now in the laboratory of Martin Gossner, a biologist at WSL. From there, the animal material is sent to experts to be determined. The bottles contain the last samples of an experiment started in 2019, in cooperation with Thibault Lachat from the Bern University of Applied Sciences HAFL, which is taking place at different sites in Switzerland and Germany. The aim is to find out how the non-native conifer fits into the local forest ecosystems. It involves investigating how the wood and litter of Douglas fir decompose in comparison with the wood and litter of spruce and beech in pure and mixed stands. The results should enable the researchers to provide recommendations for practice, such as what proportion of Douglas fir would be suitable in a forest, taking into account both ecological and economic factors.

In each of the plastic pipes are three branches of either Douglas fir or spruce or beech. The branches lay in the forest for one to three years before the researchers placed them in the pipes for a further two years. All insects and arachnids that developed under the bark or in tunnels in the wood were transported with the branches as eggs or maggots. When these hatched or crawled out of their hiding places, they fell into the bottles of alcohol while moving towards the light, where they were then preserved.

New in the ecosystem

In its native North America, the Douglas fir *(Pseudotsuga menziesii)* can grow up to one hundred metres tall and live seven hundred years. It was first planted in Switzerland around 1860. Even here, some of these non-native trees can grow to be more than sixty metres high, towering over all native trees. The Douglas fir not only grows large and tall, but also fast and straight. These features are attractive for the timber industry and have contributed to it being – after the black locust – the most common introduced forest tree here with around 870'000 specimens.

Currently, 0.2 percent of all the trees in Swiss forests are Douglas firs. This number is rising, however, be-

Photo: WSL

cause the Douglas fir tolerates drought and heat better than spruce, which is still widespread on much of the Swiss Plateau. Spruce suffers when it gets too dry and warm, which makes it less suitable in times of climate change. The North American conifer is now often introduced into plantations as a replacement for spruce, especially since bark beetles, which sometimes occur in large numbers and are a problem for spruce, have so far largely avoided it. Is this another plus point?

From the point of view of cultivation for timber production, yes, at the moment. From an ecological perspective, however, it is less ideal as Douglas fir is clearly not an integral part of European forest ecosystems and has no close relatives here. And it is still uncertain how well it will be able to fit in here and provide habitats for native species. So far, it seems, most species native to Switzerland have not adapted to the North American tree. Birds, for example, occur less frequently in its crowns in winter than in the crowns of spruce. Martin, a biologist who studies forest insects, says: "That's because far fewer insects overwinter in the crowns of Douglas firs than in those of spruce trees, and birds therefore find little food there." Further down the stem, however, it is the other way round: "The bark of Douglas firs has much more structure than that of spruce trees, and therefore attracts more insects. Birds then benefit from this," he explains.

Basis for the nutrient cycle

But these studies relate to the living tree. How do the organisms that decompose wood and litter in the forest behave? The decomposition of, for example, the branches, needles and leaves of trees that have fallen to the ground plays an essential role in the nutrient cycle of the forest. It influences, for example, how many nutrients are available for plants in the soil and how much carbon is stored there. "The rate at which the needles of the Douglas fir and spruce are decomposed is similar for both trees," Martin reports. To investigate this, the researchers filled small, net-like bags with five grammes of needles each or, in the case of the beech, with leaves from the ground. The bags were then kept in the forest for up to two years. To determine the speed of the process, the bags were later collected and weighed at different times.

"Surprisingly, the wood of Douglas firs decomposes faster than that of the native species," Martin says. However: "We found on average twice as many beetle species in the branches of spruce as in those of Douglas firs, and even in beech the species richness was somewhat greater – although it is usually higher in conifers than in broadleaves during the first years of decomposition." Moreover, an average of nearly five hundred individuals hatched from a pipe filled with spruce, whereas far fewer than one hundred hatched from a pipe filled with Douglas fir. This is relevant because the insects and arachnids that live in deadwood serve as the food base for countless creatures. Fewer insects live in the wood of Douglas fir than in that of spruce, but Douglas-fir wood decomposes faster than spruce wood. It's likely, therefore, that microorganisms such as fungi and bacteria are at work, with possibly different types or quantities in the different types of wood. Researchers at WSL and HAFL are currently investigating this. *(kus)*

wsl.ch/douglas-fir

BIODIVERSITY

Where do the flatworms, which guzzle on earthworms in gardens, come from?

It sounds like a scene from a horror film: brainless creatures covering their victims with poisonous slime to make them disintegrate and then sucking them dry! But this is really happening in some Swiss gardens and garden centres. More and more carnivorous flatworms have been spotted in recent years eating native soil organisms. One infestation hotspot has been identified in Canton Aargau.

Tests in the lab at WSL showed that this flatworm, *Caenoplana variegata*, mainly eats woodlice.

The owner of the garden there has already found hundreds of such worms – which are a good ten centimetres long. So far, five species of worms are known to have been introduced into Switzerland, most likely through the plant trade. In the whole of Europe, 28 species of soil-dwelling flatworms are natives.

How the introduced flatworms affect native soil fauna is not clear. Worried gardeners and local authorities have therefore asked WSL for advice. Beat Stierli, a member of the technical staff at WSL, hopes to find out more about the feeding behaviour and biology of two species of flatworms by feeding them with earthworms, woodlice and slugs. One of the species originates from Australia and New Zealand and eats mainly woodlice. The other, a flatworm introduced from South America, likes both earthworms and snails. This is why the introduced flatworms are considered to be a potential threat for Europe's ecosystems and cultivated land.

Beat Frey, a soil biologist at WSL, used specific genetic markers to analyse the flatworms sent in for identification. With this method he can identify the species and monitor their occurrence in Switzerland. He says: “The cantons would like to have a genetic test to identify the origin of individual specimens, i.e. which nursery they come from. But we don't, unfortunately, have the money to develop such a time-consuming test.”

It won’t be possible to get rid of these flatworms completely. They have no natural enemies in our country. Common worm-killing substances do not work. If you chop up a worm, new worms will grow from each part. The Zurich Biosafety Unit recommends using soapy or boiling water to reduce infestations. *(bki)*

Photo: Beate Kittl, WSL

BIODIVERSITY

Clearing deadwood is not good for woodpeckers

Soon the drumming sound that male woodpeckers use to demarcate their territories and attract females will be heard again in the forest. Woodpeckers start planning their families as early as February. Before laying their eggs, the pair must first chisel a nest cavity in a tree – and that takes time. A few specialists, such as the three-toed woodpecker, use mostly dead trees that are still standing for this. For them it is clearly harmful to remove deadwood from a forest area immediately after a disturbance such as a forest fire, storm or bark beetle infestation. But what about the other species of the true woodpecker subfamily worldwide? That's what Marco Basile, a researcher at WSL, and his colleagues set out to find out.

"Many woodpecker species also thrive on trees that are rotting but still alive," says Marco. "We wanted to find out how these birds – across all species – react to the loss of deadwood." Biologists from WSL, the Swiss Ornithological Institute in Sempach, the University of Zurich and other research institutes joined forces to analyse 25 data sets from North America and Europe where this had been investigated for various woodpeckers. The results are clear: in those parts of the forest where people had removed deadwood after a disturbance, indicators of healthy woodpecker populations, such as how frequently and successfully woodpeckers breed, were on average more than seventy percent less than in those places where the dead trees had been left standing. "These effects are, of course, local," Marco says. "But if woodpeckers are repeatedly unable to benefit from dead trees over large areas after a disturbance, it can certainly affect the biodiversity there."

The great spotted woodpecker, our most common woodpecker, also likes to use deadwood for foraging.

Photo: Marco Basile, WSL

Woodpecker cavities are not only useful for the birds that make them. They often occupy them for just one season. Many other creatures use the cavities, ranging from other birds like the pygmy owl, and mammals, such as pine martens or bats, to insects, plants and fungi. "If you take woodpeckers' needs into account when you are clearing up after disturbances in the forest and make sure you leave them a certain amount of deadwood, you are also protecting those creatures that benefit from woodpeckers' drilling activities – as well as all the other species that require deadwood," says Marco. *(kus)*

Basile M., Kristín A., Mikusinski G., Thorn S., Zmihorski M., Pasinelli G., Brockerhoff E.G. (2023) Salvage logging strongly affects woodpecker abundance and reproduction: a meta-analysis Curr. Forestry Rep. 9, 1–14. *doi.org/10.1007/s40725-022-00175-w*

Insect communities are changing

Insect diversity is, according to several studies, declining dramatically. Kurt Bollmann, a biologist at WSL, assesses some of the recent research.

Kurt Bollmann, people are forever talking about how insects are dying. Is it really that bad?

It depends on which species groups and habitats you consider, as well as on the scale and time period you are looking at. We have, for example, data on insects in the Limpach Valley, in Cantons Bern and Solothurn, for the years 1987, 1996 and 2019. The records include information on the species richness and abundance of different groups, as well as their total weight, which we refer to as biomass. Our analyses indicate that all three parameters have increased quite significantly.

This goes against many other findings. Are they all wrong?

No, I wouldn't say that. So far, however, the focus has been primarily on the diversity rather than the abundance and biomass of insects. This is why we are cooperating with four other research partners on the INSECT project to investigate the effects of changes in climate and land use on both the composition of different insect communities and the abundance of different groups and insect species over the past decades. Data on diversity alone is less relevant for assessing nutritional relationships in ecosystems than data on biomass.

In what way?

Insects are a valuable source of energy for many fish, birds and small mammals, part of whose main diet consists of common species of insect. They play an extremely important role in ensuring the survival and reproductive success of these creatures.

But insect diversity is also important, isn't it?

Of course, from the perspective of conservation biology it is very un-

Kurt Bollmann is a biologist and head of the Conservation Biology Group at WSL.

In the Limpach Valley (in Cantons Bern and Solothurn), the abundance and biomass of insects have gone up since 1987. This increase is probably due to the warmer climate and the expansion of ecological compensation areas.

Photo: Martin Obrist, WSL

fortunate when rare and specialised insect species, such as large insects like the mole cricket, become extinct in a region. Since their decline, bird species such as the lesser-grey shrike or the hoopoe have disappeared as breeding birds in Switzerland or become very rare. We clearly have a special responsibility for the insect species in the Alps that occur only there, but they contribute little to the overall biomass of insects.

What has caused the changes in insects?

Within a short space of time, the landscape has changed tremendously. It has gone from being diverse and structurally rich to becoming more uniform. Large areas are now managed intensively in the same way. Wetlands have shrunk to small remnants of their original extent and gradual transition areas between habitats are often missing. Population growth and social change have certainly also had an influence, with large areas of land being sealed and an increase in artificial light.

And what role does climate change play?

A central role. Insect development and activity are temperature-driven. It is therefore not surprising that the abundance of numerous species increases when it gets warmer. Initial results from the INSECT project indicate that insect communities are becoming reorganised due to the influx of thermophilic species.

But the cold-loving species are disappearing?

Not necessarily. In our study on aquatic insects in Swiss waters, we

The native blue-winged damselfly *(Calopteryx virgo)* is common around flowing water. It has become much more widespread in Switzerland over the past forty years.

were able to show that species numbers remained stable within the ten years studied, even for species that prefer the cold. The results surprised us, so we extended the data set to thirty years in a follow-up study with cantonal data. The results were the same, and we could detect no general decline. However, cold-loving species are likely to become rarer in the future.

Then is it the case that insects are not dying off as much as feared?

The findings indicate that, at least in Switzerland, there has been a reorganisation of insect communities over the past thirty to forty years rather than a widespread die-off of insects. *(lbo)*

wsl.ch/insects

Photo: Beat Wermelinger, WSL

LANDSCAPE

Avoiding conflicts, preserving biodiversity and planning recreation

Twice a week – from spring to autumn – more than half of the people in Switzerland go to the forest to unwind. Many are also out and about in the mountains, or on riverbanks and lakes. They enjoy going on walks, hikes or bike tours. According to a WSL study, they all consider near-natural recreational areas to be particularly attractive, but these areas are also valuable habitats for plants and animals.

A new WSL web app, which is freely accessible on the internet, should help in future to steer visitor flows in such a way that leisure activities have as little impact on nature as possible. The app simulates the recreational use of an area in Switzerland that users can freely select. It then shows, on the same map, the number of sensitive animal and plant species there and how threatened they are. To ensure an intuitive, easy-to-understand user interface for all target groups, a steering group of experts on nature conservation and planning accompanied the project, which was financed by the Biodiversity Centre at WSL.

Near-natural lakes are not only popular excursion destinations, but also valuable for many animal and plant species.

The information on flora and fauna comes from InfoSpecies, the Swiss Information Centre for Species, while that on recreational users comes from population data and studies of leisure activities. “We used the data on population and recreation to generate “agents”,” explains Johan Früh, a social scientist at WSL. “These are figures who move around the area’s trail network simulating people. They can, for example, represent a biker or a hiker.” The simulation allows planners to see which roads to a recreation area or within it are particularly popular, and thus where there could be conflicts with the protection of local flora and fauna.

The researchers verified that the behaviour of the “agents” is actually realistic by asking people in the Glatt valley near Zurich where they spend their free time. Their responses reflected the results of the app. Johan says: “With the help of the app, it should be possible to find ways to reduce recreational pressure on sensitive areas by, for example, steering visitors away from them.” *(kus)*

wsl.ch/visitor_flow

Photo: Michael Müller

Finding a way to get to net zero

In the Federal Parliament in Bern, the Federal Council decided – in 2019 – that Switzerland should be climate neutral by 2050.

Photo: Parlamentsdienste 3003 Bern/Béatrice Devènes

Switzerland committed itself to becoming climate neutral by 2050 as part of the Paris Climate Agreement. “Achieving this aim requires a fundamental change in the economy, politics and society,” says Annina Guthauser, a doctoral student at WSL. “It will only be successful if it receives broad support from the government, politics, the economy and civil society.”

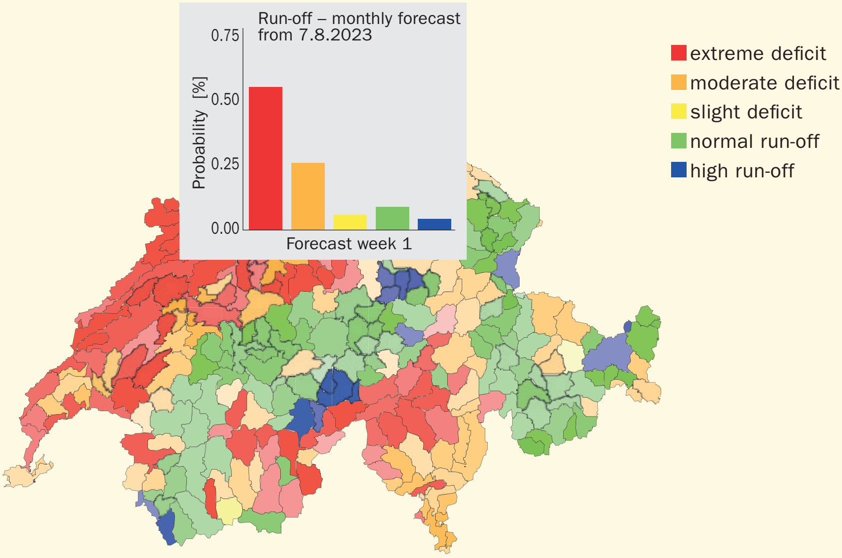
To find out which factors promote such processes and which slow them down, Annina and a project team at WSL examined transformations that have taken place in Switzerland. These include the Forest Police Act of 1876, which introduced sustainable forest management in Switzerland, and other far-reaching changes in the areas of biodiversity, landscape and natural hazards.

It turned out, Annina says: “that having a common vision or a jointly defined goal is beneficial – and the net-zero goal could be just such a goal.” Where a transformation affects many aspects of society, a broadly-based discussion process is needed to promote the change. Obstacles include a lack of awareness of the problem among the general public, as well as the existence of groups that are able to assert their own interests. Switzerland’s federal system can also make transformations difficult – but having committees with representatives of all the political and administrative levels affected can help steer processes in the right directions.

Procedures that facilitate transformations therefore do exist. But one factor makes the path to climate neutrality more difficult – time. Annina explains: “Unlike past transformations, these changes have to happen at the same time and take place quickly. But the year 2050 is just around the corner.” *(job)*

Guthauser A., Pütz M., Seidl I., Olschewski R. (2023) How to achieve the net-zero target? Lessons learned from past transformations PLOS Sustain. Transform. 2(6), e0000068 (27 pp.). *doi.org/10.1371/journal.pstr.0000068*

Drought and its consequences: extension of the forecasting platform



The new extension of drought.ch shows the risk of various impacts of drought.

Will streams burst their banks within the next two weeks because of meltwater or is the risk of forest fires likely to dangerously increase in four weeks' time? As of 2024, it should be possible to consult the map of Switzerland on the extended Internet platform drought.ch to clarify such questions – or at least find out how likely it is that such events will occur in the following four weeks compared to the long-term average.

"The aim is to present, on a single platform, the information and warnings in an intuitively understandable way, using colours of different intensity," says Konrad Bogner, the researcher at WSL who coordinates the associated sub-project MaLeFix (Machine-Learning-aided ForecastIng of drought-related eXtremes) of the WSL research programme "Extremes". "The extension of the platform includes the impacts of other extreme events. For example, it depicts not only drought in the forest, but also the risk of forest fire." To help select what to include and how to present it, social scientists conducted interviews with potential users at the start of the project.

The monthly forecasts of MeteoSwiss provide, together with hydrological models, the basis for the models which the researchers are currently linking in order to predict risks ranging from glacier melt to bark beetle danger. Comparisons with data from earlier dry years have shown that the forecasts correspond well with reality. The accuracy of the predictions will be monitored and improved through machine learning. *(kus)*

wsl.ch/malefix

Photo: WSL

Laser beams in the Illgraben

The police use it to catch drivers speeding, builders measure distances with it, and car companies consider it an important component for developing self-driving cars and autonomous driving. "It" refers to LiDAR, a method for sensing the local environment three dimensionally with the help of lasers. Researchers at WSL also use it for studying – among other things – debris flows in detail.

The first time it was used like this was on 19 September 2021, when a debris flow, i.e. a mixture of mud, water and boulders, flowed for around half an hour in the Illgraben in Canton Valais. The WSL researchers were able to record it and take measurements over a thirty-metre stretch above a check dam with their permanently installed LiDAR scanner. Up until then, it had been difficult to analyse what happens in detail during a debris flow. The measurement data they obtained provided just such information.

"The results show that the flow is very uneven and unstable," says Jordan Aaron, a visiting scientist at WSL. For example, the material behind the front of the debris flow moves at a consistently greater speed than the front itself, and slows down the further forward it gets. The material consists of boulders of different sizes and shapes as well as wood, for example branches and tree stems.

One reason little was known in detail about debris flows earlier is that the material flows at relatively high speed – more than 18 kilometres per hour on this particular day in the Illgraben. Jordan and his colleagues therefore relied on the LiDAR sensors used in self-driving cars for their measurements and modified them: "The scanners provide ten images per second, which means both the temporal and spatial resolution are high." With the images, the researchers can then measure the speed of the boulders and wood debris on the surface of the debris flow.

Illgraben monitoring station: a debris flow hurtles down from the left towards the valley. Researchers at WSL use a LiDAR scanner to measure its behaviour in detail with high spatial and temporal resolution.

Jordan is confident this approach will make it easier to compare experimental observations and models of debris flows. He says it should also be of benefit for people in endangered zones as the results improve our understanding of how debris flows move and enable more accurate forecasts: "This is crucial for providing targeted measures to cope with the dangers they cause." *(job)*

Aaron J., Spielmann R., McArdell B.W., Graf C. (2023) High-frequency 3D LIDAR measurements of a debris flow: a novel method to investigate the dynamics of full-scale events in the field Geophys. Res. Lett. 50(5), e2022GL 102373 (10 pp.). *doi.org/10.1029/2022GL102373*

Photo: WSL

Tough competition on the way into space

Data from space is helpful for studying snow and ice on Earth (Artist's impression of the Cryosat research satellite).

In 1958, the small metal sphere had been sending radio signals for three weeks before it burned up in the Earth's atmosphere after 92 days in space. Sputnik 1 was the first satellite to be launched into the Earth's orbit. Modern space satellites are much more complex and can be used to explore not only space, but also the Earth's surface. Researchers at WSL and SLF also use satellite data and are participating in the development of new space-based measurement concepts.

At WSL, such data is being used to, among other things, observe how forests are developing. It helps researchers to determine where drought is severely affecting trees and to estimate the extent of storm damage.

Researchers at SLF in Davos are extending their collaboration with the European Space Agency (ESA). They have already been involved in drafting a proposal for a new satellite mission. The selection process on the path to a successful partnership is laborious. ESA first calls for applications for missions and invites applicants to submit ideas. Numerous consortia, mostly from leading ESA member states, then propose what they want to measure with a new satellite, as well as how and why they want to measure it.

"It is difficult to realise an idea for measurement in such a way that it is, in the end, taken along on a new satellite mission – the competition is tough," says Henning Löwe, head of

Photo: ESA – AEOS Medialab

the Snow Physics research group at SLF. The space agency repeatedly sorts out – in several rounds – which ideas it considers unsuitable, which do not meet the strict scientific or technical levels of development required or the programmatic specifications. "In the process, it checks to see, for example, whether a project has managed to achieve clearly defined goals by given deadlines to ensure that the technology is certain to function flawlessly by the time the satellite is launched," Henning explains.

The researcher and his team first took part in a satellite mission in 2009. Back then, they measured various properties of snow on behalf of ESA and the Finnish Meteorological Institute. "That was our entry into collaboration with ESA," recalls Henning. His most important project started in 2015, which led to the development of the Snow Microwave Radiative Transfer (SMRT) model. With this computer-based method, the microstructure of snow can be determined from space and snow quantities estimated. Henning has been training other researchers how to do this for years – which means that the next generation is ready. *(job)*

SNOW AND ICE

All just a lot of hot air

It was about the worst thing that can happen to snow researchers. When Dylan Reynolds and Michael Haugeneder reached their experimental field site at the Rocky Mountain Biological Laboratory, an open-air laboratory in the US state of Colorado, in May 2023, there was no snow left. The region had experienced one of the most intense snowmelts ever in the spring of 2023 after a winter with lots of snow. Dylan and Michael swore loudly.

The two snow physicists from SLF in Davos had reserved two weeks for their work. But instead of taking measurements straight away as planned, they first had to collect many sledge-loads of snow from the surrounding area to create a snow field under the experimental installation they had set up. This, however,

The snow laboriously transported by hand under the experimental installation at the Rocky Mountain Biological Laboratory in the US state of Colorado.

Photo: Michael Haugeneder, SLF

melted again so quickly that, in the end, they only had four days for their research.

High resolution close to the ground

Nevertheless, the two managed to obtain some important insights. "The snow melts, for example, faster in Colorado than in Switzerland," Michael explains: "This is partly due to the dust-on-snow effect, where the dust on the surface of the snow causes the ground to warm up more quickly." He is investigating how the air warms up over the first patches of snow-free ground in spring, and then moves from these spots to snow-covered areas where it accelerates snowmelt. He made his first measurements at Dürrboden in the Dischma Valley near Davos and at Monbiel near Klosters.

The physicist points an infrared camera at two screens of thin polyester, each about five square metres in size. He uses them to film how the air moves above the snow cover. The recordings show – impressively – how the warm air moves from snow-free to snow-covered patches. What is special about Michael's installation is its high spatial resolution. This makes it possible to measure very close to the snow surface. In combination with a high frequency of 30 images per second, he was able to obtain detailed results: "With this system we can observe the interaction of wind and warm air directly above the snow surface."

The results from the open-air lab in Colorado supplement those from Switzerland with values from a region with different climatic conditions. The data from the USA is also of interest for American research groups.

Important for the economy and for disaster control

Michael's results on snowmelt help not only to improve the models for estimating future drinking-water supplies. "They also make it possible to predict floods and forecast the potential of hydropower plants," the physicist explains. This means they are just as important for water and energy suppliers as they are for disaster control.

Moreover, the processes involved also play a role in glacier melt. For example, what are the effects on ice masses when air heats up over rocky ground in summer and the wind transports it over the ice? Michael's research contributes basic principles for clarifying this.

He had already been to the USA in autumn 2022 to install the measurement system he had developed, together with his cooperation partners from the University of Washington, as part of an extensive measurement campaign. The Americans had used his system earlier in the year. The researchers from the University of Washington were mainly interested in exploring effects with a closed snow cover in winter. Michael needed the first snow-free spots – and got more of them than planned. *(job)*

slf.ch/snowmelt_blog

Photo: Bruno Augsburger, Zürich

Kavitha Sundu, Davos

"After lunch I like to go to Lake Davos. The circular path offers a beautiful view of the mountains, trees, water or – at the moment – ice. I often go with friends from SLF. While walking, we can have a good chat.."

ARCHIVE IN ICE

"Snow is an exciting material. I enjoy getting to understand the complex processes in the snowpack better and better." Kavitha Sundu is a computational engineer, who is studying how snow gets deformed under the pressure of the upper layers. Her findings should further our understanding of how snow compresses into ice over time, and "archives" the composition of the atmosphere. This information is important for studying variations in the Earth's climate over millennia. *(sni)*

MEASURING A SNOW PROFILE IN 1935

An employee of the Snow and Avalanche Commission, which was founded in 1931 and was the predecessor of the WSL Institute for Snow and Avalanche Research SLF in Davos, measures a snow profile beside the Saflisch Hut. The hut, near Brig in Canton Valais, was one of the Commission's five stations in the 1930s. The dark lines in the snow are probably needles that had fallen from the surrounding trees. It involved the same kind of work as today: before you can measure, you have to dig. *(job)*

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