WSL MAGAZINE

DIAGONAL

FOCUS

Wood and more: changing forest use

No. 1
20

Swiss Federal Institute for Forest, Snow and Landscape Research WSL

EDITORIAL

Dear reader

In the old farmhouse where I live, I have set up an office in the attic. Here I can work in peace and quiet when I have to work from home. I can hardly imagine a more beautiful workplace. It contains so much wood: the old roof beams, the wall panelling and the parquet flooring, which radiate a warmth and comfort that no other material can create.

Building houses or furniture out of wood makes more sense today than ever before: not primarily because it's cosy, but because it helps in the fight against climate change. Trees filter the greenhouse gas CO_2 out of the air, which also remains bound in the wood after the tree has been felled. How should Swiss forests be managed and how should the harvested wood be used to bind as much CO_2 as possible for as long as possible? WSL researchers provide answers to these questions (see page 10). In this way they are also contributing to climate protection. If this also creates more comfortable living atmospheres and workplaces – all the better!

Prof. Dr. Konrad Steffen
Director of WSL

FOCUS

Wood

MORE THAN JUST A SUPPLIER OF WOOD

Forests fulfil many important functions: providing protection against natural hazards, filtering drinking water and serving as a habitat. How can these services be maintained – and who should pay for them?

→ **2**

WOOD FOR THE CLIMATE

Trees absorb CO_2 from the air: 925 million tonnes of it are stored in Swiss forests alone. This climate protection effect can be further increased so long as the wood is used cleverly.

→ **10**

DESTRUCTIVE POWER

Large wood in rivers can knock down bridges and block weirs. New findings help to assess the risks better.

→ **12**

SOMETHING IS GROWING HERE

In Valais, WSL researchers are investigating how a warmer climate influences the growth of trees and thus wood formation.

→ **14**

KEY TOPICS

PORTRAITS

Photos: Cover: Michel Lüthi/bilderwerft.ch; Julia Wessels, SLF; Table of contents: Wood: Markus Bolliger, BAFU; Climate: Ueli Wasem, WSL; destructive power: Nicolas Steeb, WSL; Valais: Patrick Fonti, WSL

FORESTRY Few forest enterprises in Switzerland today can make money producing and selling wood. And yet the forest is still expected to perform manifold services for the general public. These, however, are not to be had for free.

A forest for everything

Effective maintenance of the protection forest would not be possible without significant support from the federal government and the cantons.

WSL researchers are developing an IT-Tool for planning when to use cable crane systems quickly and easily.

Mountain forests must be maintained to ensure they provide sustainable protection against natural hazards. This involves using cable devices, such as this mobile tower yarder with a mounted processor, which is complex and expensive.

Rothenthurm (Canton Schwyz), April 2015.

Photo: Fritz Frutig, WSL

When forest owners inspect their forests, they need, at the same time, to envisage what they will be like in at least fifty to a hundred years. Today, a forest may contain many spruce trees of the same age, but these could die off during the next dry period. Should the owners harvest the trees now in order to get a still acceptable timber price, and plant more climate-resistant Douglas firs or – even better – species of oak? If the forest is close to nature, a bird conservationist may have spotted a rare white-backed woodpecker in it. Perhaps the forest could become a natural forest reserve and provide the bird a long-term home. In that case, should the forest owners give up harvesting the wood in future and apply for subsidies instead?

The measures adopted by a forest enterprise today will not only influence, for many decades to come, the development of the forest and its services for society, but also the enterprise's own economic survival. The sector is currently in difficulties, with more than half of Swiss forest enterprises running at a loss (see the Interview on page 7).

Since it first began, WSL research has supported forestry by developing planning tools for the ecological and cost-efficient use of forests. These include models that optimise the organisation, planning and implementation of forestry measures, such as: calculating timber growth, estimating the costs and yields for various timber-harvesting operations or efficiently planning complex operations like the use of temporary timber transport cableways. "We have designed these models to be good, simple, user-friendly and transparent," explains Janine Schweier, head of WSL's 'Sustainable Forestry' Research Group.

The challenges facing foresters and forest owners today, however, involve issues that are not just technical. This is why at WSL the research focus will, in future, increasingly go beyond the operational level. The forest can no longer be considered as just a supplier of timber and wood for energy. It should protect residential areas and infrastructure against natural hazards, provide a habitat for a wide variety of animal and plant species and enable people to spend their leisure time there unrestrictedly. It is also taken for granted that forests filter drinking water and remove CO_2 from the atmosphere.

All of these objectives are set out in the government's Forest Policy 2020, which forestry must abide by. WSL supports the implementation of the policy through research. It is a juggling act. "The more diverse the goods and services the forest is expected to provide, the more challenging the planning and decision-making becomes for forest enterprises," says Janine, who is a forest scientist. The magic formula is 'multifunctional forest planning'. WSL researchers have calculated exemplary ways of promoting biodiversity to achieve this goal in the former forest enterprise Wagenrain near Bremgarten (Canton Aargau). Simulations of four management scenarios over a fifty-year period suggest that the scenario where forest areas contain separated off nature reserves is the one that works best for biodiversity protection. It also fulfils other functions at the same time, such as making the forest more attractive for visitors.

Research group 'Sustainable Forestry': *www.wsl.ch/sustainable-forestry*

The 'Resource Analysis' Research Group at WSL has a new project that is even broader in scope and aims to predict for entire regions how harvesting the wood impacts on forest services. Using data from the Swiss National Forest Inventory (NFI) and climate data, the model estimates how large the trees on the NFI sample plots will become over time. The effects of increasing or reducing the wood harvest on forest development can then be simulated. The calculations in the model show how the trees and forest stands will develop so that estimates can be made for various forest services, for example of wood volume, as well as of carbon in the soil as a CO_2 sink, or of deadwood, which is an important habitat for many animals. "When making management decisions, the model can help in opting for one or more of these objectives," explains Esther Thürig, the biologist who heads the Research Group.

Storms and bark beetles

Careful long-term planning is, however, increasingly being drastically affected by unforeseeable events. Foresters and forest owners today already have to harvest about half of the annual timber yield in connection with emergencies, like storms and bark beetle infestations. 2018 was a dramatic year: the summer was extremely dry, and the storms Burglind and Vaia resulted in three instead of the usual two generations per year of bark beetles. Forest enterprises and sawmills worked to full capacity, and the price of spruce wood/timber fell by around a third.

"Unfortunately, years like 2018 are likely to become more frequent with climate change," says Janine. That's why Janine wants to support forestry in future research projects to help plan for the unpredictable, addressing questions such as: how best to cope with the immense quantities of windthrown wood; or how to drive with heavy machinery over difficult terrain where the

Storms and bark beetle mean Swiss sawmills are working to full capacity. This, together with competition from imported timber, means that the price of timber remains low.

Photo: Emanuel Ammon, BAFU

Research group 'Resource Analysis': *www.wsl.ch/ resource-analysis*

ground is still soft because warmer winters mean it is frozen for shorter periods.

In addition to these issues, Swiss timber is difficult to sell. In the past, it was assumed that exploiting the timber would more-or-less automatically co-finance all the other forest functions and thus enable their performance. This assumption was known as the 'Kielwassertheorie' ('wake' theory), which no longer applies. Prices for timber are low, and domestic timber suppliers are finding it hard to compete with timber that is often imported more cheaply.

Foresters and forest owners are therefore requesting compensation for non-timber forest services – similar to the ecological subsidies in agriculture. In forests, the federal government currently provides support only for the maintenance of protection forests in mountain regions and specific measures to preserve biodiversity and adapt to climate change. "People in Switzerland consider certain forest services, such as clean drinking water and recreational opportunities, as 'public goods' for the general public and expect them to be provided free of charge," explains Roland Olschewski, Head of the WSL Research Group 'Environmental and Resource Economics'. "This makes it difficult to market ecosystem services."

'Premiums' for protection forests

The forest economist is investigating, among other things, how willing the public in Switzerland is to pay for forest services. As part of the National Research Programme 'Sustainable Economy', his team has asked households in various municipalities in the Grisons and Canton Valais whether they would be willing to pay for additional forest maintenance that would increase the protection of their homes against natural hazards such as avalanches. The result: the majority of households were very willing, in this case, to pay an extra 'insurance premium' for the protection forest. Other researchers have also found that people, especially in urban areas, would be quite willing to pay between CHF 80 and 200 per year to be able to visit the forest.

Research group 'Environmental and Resource Economics': *www.wsl.ch/environmental-resource-economics*

A few forest owners have detected an opportunity to sell various special forest services on a voluntary basis: tree or forest sponsorships, private natural forest reserves, or 'climate' forests for the long-term storage of the greenhouse gas CO_2. Other potential income sources could be renting forest huts or organising forest kindergartens. In forest cemeteries, the deceased can find their final resting place under trees.

Such opportunities cannot, however, compensate for the costs and risks involved in forest management, especially for private forest owners without tax revenues. In this situation, WSL research can help, for example by suggesting how the value of forest services can be expressed in Swiss francs or how to resolve conflicts between different forest management objectives. Roland is convinced that there is no way around having the public pay for some ecosystem services in the long term. "This is the only way to ensure their long-term viability." *(bki)*

INTERVIEW **"Forest services should no longer be free of charge."** Falling timber prices mean that the services the forest provides for the entire population should be reconsidered. How are Swiss forest owners reacting to this situation? Urban Brütsch, Deputy Director of WaldSchweiz (Forest Switzerland), responds to our questions.

Mr Brütsch, more than half of Swiss forest enterprises are currently operating at a loss. Why is this?

UB: In the past, the revenues from timber covered the entire costs of the forest enterprises and owners. The profits could be used to invest in infrastructure or machinery in order to work more cost-effectively again, or to finance other forest services. This has not been the case for many forest enterprises for a long time. Thus, from a financial point of view, timber production has become increasingly less important.

What are the consequences?

UB: If losses continue to be high, some forest enterprises will have to restrict or even stop forest management. However, a forest needs to be tended regularly in a targeted way to keep it stable and fit for climate change. Moreover, it should offer many services, such as providing protection against natural hazards, filtering drinking water, conserving biodiversity and providing recreation opportunities. This would then become difficult.

How can this be solved?

UB: All that can be done is to consistently reduce costs further or generate new income, for example by offering and marketing 'non-timber forest services', such as recreational facilities or CO_2 storage capacity. Private forest owners without tax revenues are increasingly providing the services the public wants – or even demands – so far mostly free of charge. They will no longer be able to continue to do this.

Some forest owners have begun to offer tree patronages, forest sites as last resting places or CO_2 storage certificates. Will this make it possible to finance forest management in the future?

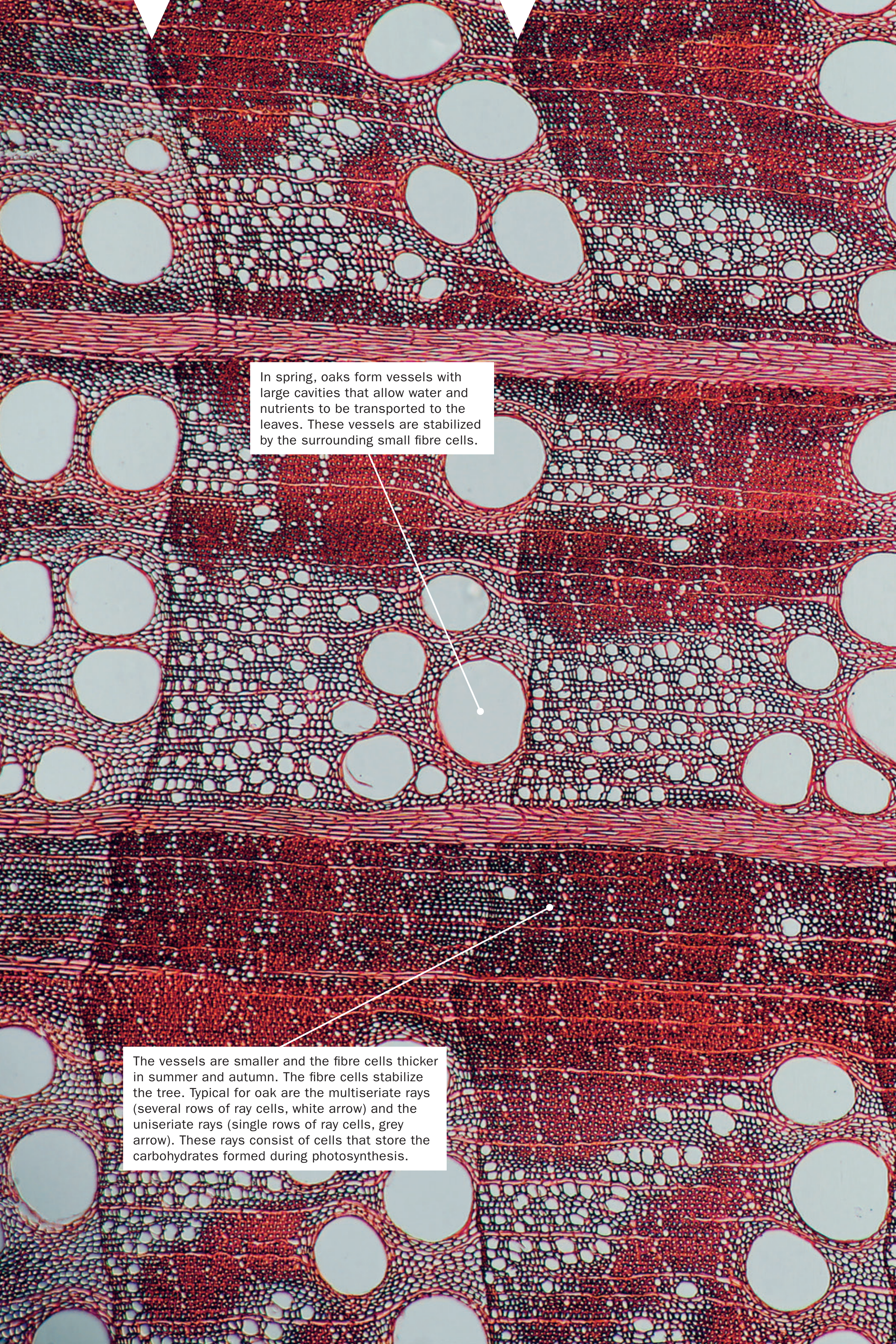
UB: There are some positive examples where additional revenues are generated in this way. Most forest enterprises and owners have not, however, fully exploited this potential. Concrete agreements with the beneficiaries will be necessary to be able to generate revenues from forest services.

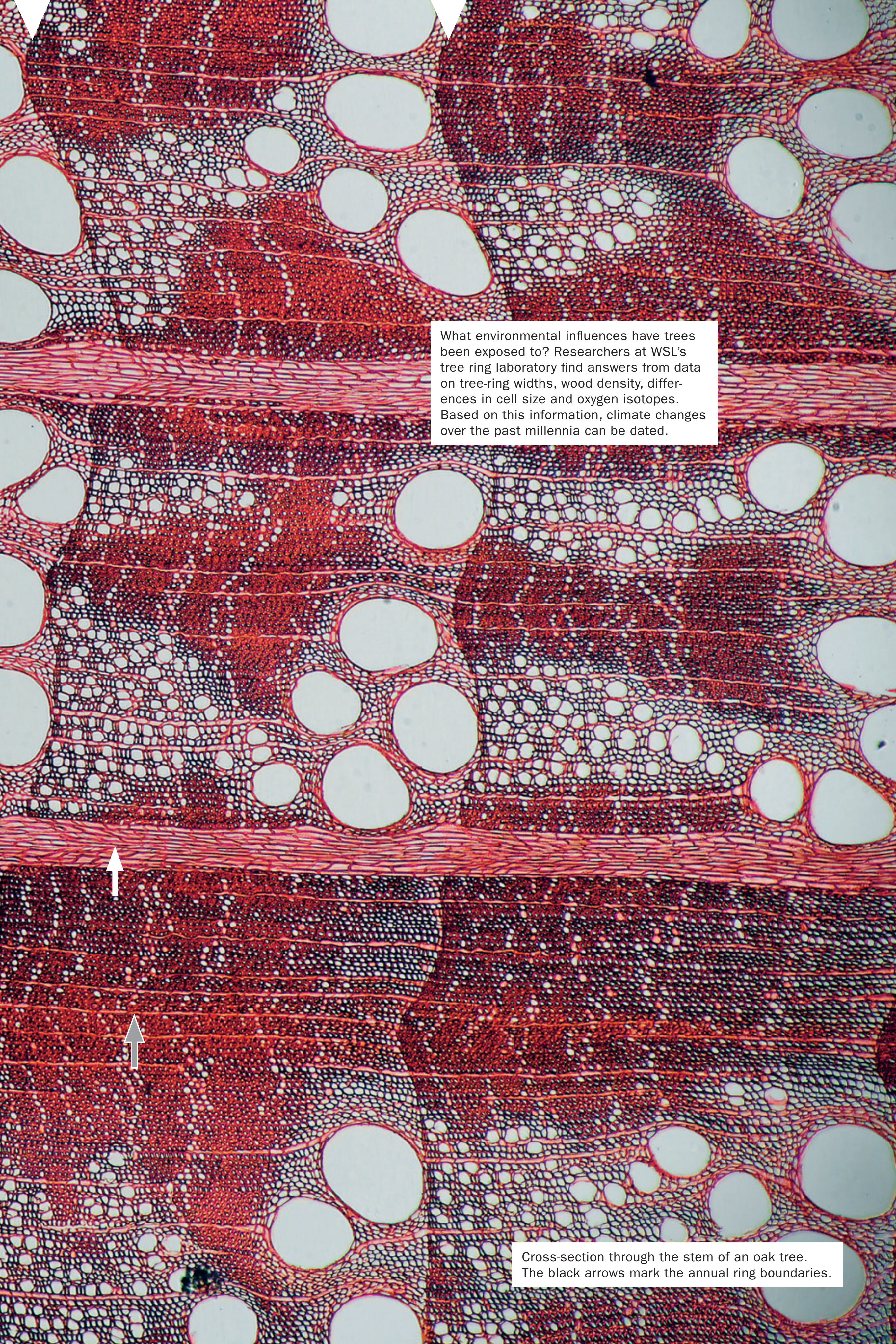
How can WSL research help here?

UB: Non-timber forest services are not often in much demand commercially. Tools for calculating the value of these services would be helpful. Such tools already exist for drinking water storage. It would also be valuable to have support in implementing research results in practice, for example by quantifying the recreational benefits of managed forests and of systematically paying for them. *(bki)*

The forestry engineer Urban Brütsch is Deputy Director and Head of Economics at WaldSchweiz, the Association of Swiss Forest Owners.

Photo: zvg; Photo pages 8/9: Tree-ring lab WSL


In spring, oaks form vessels with large cavities that allow water and nutrients to be transported to the leaves. These vessels are stabilized by the surrounding small fibre cells.
The vessels are smaller and the fibre cells thicker in summer and autumn. The fibre cells stabilize the tree. Typical for oak are the multiseriate rays (several rows of ray cells, white arrow) and the uniseriate rays (single rows of ray cells, grey arrow). These rays consist of cells that store the carbohydrates formed during photosynthesis.



What environmental influences have trees been exposed to? Researchers at WSL's tree ring laboratory find answers from data on tree-ring widths, wood density, differences in cell size and oxygen isotopes. Based on this information, climate changes over the past millennia can be dated.

Cross-section through the stem of an oak tree. The black arrows mark the annual ring boundaries.

SUSTAINABILITY **Wood for climate protection.** Forests bind lots of CO_2. As a renewable resource, wood is climate-friendly. But how should forests in Switzerland be tended and the wood be used to ensure the best climate protection?

A large beech tree removes up to eight tonnes of CO_2 from the atmosphere during its lifetime, storing the carbon in its stem, roots and branches. According to calculations published by Esther Thürig, head of the 'Resource Analysis' Research Group at WSL, her team and other colleagues from consultancy offices and universities, around 925 million tonnes of CO_2 are stored in Swiss forests. Half of this CO_2 is stored in the forest soil, and the other half in the trees. This CO_2 reservoir is equivalent to almost twenty times Switzerland's annual CO_2 emissions. There is clearly a need for more forest. Larger areas of forest lead to less CO_2 in the air – which means that emissions can be cleverly offset.

In Switzerland, however, there is hardly any room for more forests – except in the Alps. The question is therefore much more whether and how the existing forests can bind more carbon. Currently more wood is growing in Swiss forests than is harvested – especially in the Alps, where harvesting timber is costly and economically unattractive. But as Esther, who is a biologist, warns: "The forest does not always serve as a sink for carbon. It can also become a source!" For example, when storms like Lothar sweep across the country, trees are uprooted or blown down. They then rot and release CO_2 in the process. The same applies when trees die due to drought or bark beetle infestation or burn in a forest fire. With climate change, such events are expected to become more frequent.

Wood used for construction stores carbon

Moreover, from the point of view of forest management, where the forest edge is the system boundary, every tree stem that is removed from the forest reduces the carbon stock in the forest – regardless of whether it was harvested regularly or blown down in a storm, and regardless of how the wood is used afterwards. This does not mean, however, that CO_2 is actually released into the air. If the wood is used in furniture or buildings instead of more energy-intensive materials such as concrete, the carbon remains bound in the wood. It therefore makes most sense to investigate the effects of forestry and the timber industry in combination.

This is what Esther Thürig and her colleagues have done: they considered a total of five scenarios, i.e. possible future developments, and calculated their impact on Switzerland's carbon balance. The range of possible 'futures' extends from increased use of wood for building and heating, through the continuation of current trends, to significantly fewer trees being felled than today. "It may come as a surprise at first glance," Esther comments, "but letting as many large old trees as possible grow is not the best way to protect the climate in the long term." The further into the future you look, the clearer it becomes that the


To remove as much CO_2 from the atmosphere as possible and thereby protect the climate, the use of forests and wood should be promoted – first for construction and then for heating.

scenario with intensified but still sustainable use of wood binds the most carbon. To express this a bit more precisely: in order to extract as much CO_2 from the atmosphere as possible in the long term, forests should be managed to produce more wood than they do today. And the indigenous wood they produce should be used in building. When a wooden building comes to the end of its life, the wood it is made of should be burned and the heat used. When wood is used like this, it contributes to climate protection in various ways. It not only creates a larger CO_2 reservoir, but it also replaces energy-intensive building materials before the wood in the old building is used as a substitute for fossil fuel. This could, in the long term, reduce the annual CO_2 emissions of Switzerland by around five percent.

Photo: Markus Bolliger

This scenario cannot, however, be implemented at the push of a button. Since the economic viability of exploiting the forest has deteriorated (see page 3), it is not the case that more wood is currently being harvested – so it is not possible to use more wood for construction. The problem is aggravated by the fact that Swiss forests will, in future, supply increasingly less spruce wood because spruce trees are poorly adapted to the predicted future climatic conditions. The wood from the deciduous trees that grow in their place has rather different material properties. Neither sawmills nor carpenters can process it so well and at such a cost-covering level as today's spruce timber.

Promoting carbon sinks

Esther is currently updating the scenarios to take into account, in particular, the current situation and the latest research findings from the simulation models. It is especially important to know how the carbon balance will be affected if things go on in the same way and current trends continue, for example if the price of wood continues to fall. This is the basis for comparisons to assess whether and how well climate protection measures work. Both forestry and the timber industries are trying to process the sink performance of their particular subsystems. For example, private individuals or companies can purchase CO_2 certificates from the 'Oberallmeindkorporation Schwyz' to voluntarily offset their emissions. In return, the corporation is increasing wood production in its forests in a controlled and sustainable manner.

A year ago, forest owners and forest managers also founded the association 'Wald-Klimaschutz Schweiz' ('Forest Climate Protection Switzerland'). This association aims to help its members sell the service their forests provides as carbon sinks on the CO_2 markets. Switzerland is, after all, meeting a considerable proportion of its international commitment to reduce CO_2 through its forests. The additional revenues could help to steer management even more specifically towards climate protection. The timber industry is pursuing similar objectives and has founded its own association 'Verein Senke Schweizer Holz' ('Swiss Wood Sink') in the hope of obtaining some of the money from the CO_2 compensation funds through promoting the use of wood and binding more carbon in the wood it uses.

The scenarios and models developed by Esther and her colleagues provide valuable information for developing effective compensation payments or subsidies. They also help to improve the accuracy of Switzerland's greenhouse-gas reporting for the international community. *(bio)*

ILLUSTRATION

Wood as a habitat

Old, dying or dead trees provide a habitat for many animals, plants and fungi. They may serve as a source of food for them as well. A tree may, depending on how much it has decayed, be colonized by various species of wood-decomposing fungi and beetles, which then make the nutrients available again.

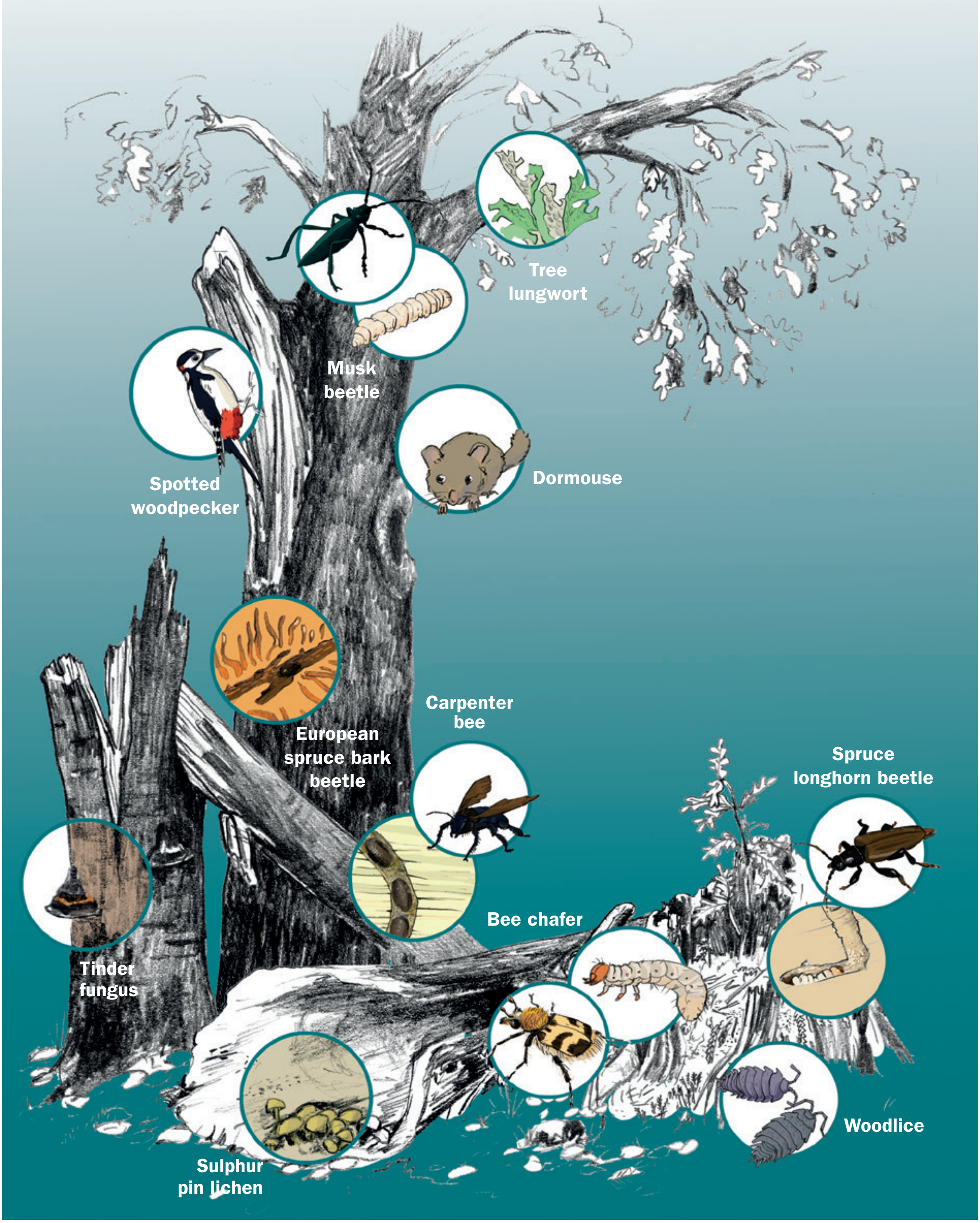


Illustration: Yvonne Roggenmoser, Zurich

Making sure large wood does not become a danger. Floods carry away branches and tree stems that can destroy bridges or block weirs. A research programme provides practical help to enable better forecasting of future flood-timber volumes.

Wood in stream- and riverbeds promotes biodiversity because it provides habitats and food sources for animals. But if a river transports branches, shrubs or entire tree stems with it during floods, this could be dangerous for people and infrastructure. Large wood can block weirs, damage bridge piers or result in entire residential areas being flooded by backwater.

During the extreme floods in 2005, more than 100,000 cubic metres of large wood accumulated in Switzerland – the equivalent of around 2500 truckloads. “The quantities, however, vary greatly between individual flood events,” says Nicolas Steeb, a researcher in the ‘Torrents and Mass Movements’ Research Group at WSL. That’s why it has, until now, been difficult to predict where and how much large wood will occur.

To obtain better estimates in future, the Federal Office for the Environment (FOEN) set up the ‘WoodFlow’ research programme with researchers from WSL, ETH Zurich, the Bern University of Applied Sciences and the University of Geneva. Over a period of four years, they investigated the origin, transport and deposition of large wood. “The aim was to create a knowledge base for practical applications,” says Nicolas. They developed, among other things, various tools for government and engineering offices. With these tools, they can calculate, for example, what the minimum distance between the water level and the bottom of a bridge should be to prevent the bridge being damaged by large wood.

For further information on WoodFlow, see: *woodflow.wsl.ch*

How much large wood could accumulate?

Nicolas developed, in his part of the project, a practical GIS model for predicting the large wood potential of different catchment areas. This involved modelling processes, such as debris flows, landslides and riverbank erosion, and combining them with maps of the river network and forest areas. He also integrated into the model a map of the wood stock, which indicates the amount of wood present in an affected forest area. On the basis of this and other data, the model calculates the potential amount of large wood that could, statistically, be produced every 30, 100 or 300 years during major flood events. The local authorities can then use this information to plan appropriate protection measures in their respective regions.

In another sub-project, Nicolas investigated the wood’s size distribution. For this, he used data on around 6000 pieces of large wood that WSL measured after the floods of August 2005. Most of the pieces found were between one and three metres long. Very large pieces were rare. Much of the wood gets considerably broken up while being transported in the water. From the length

The flooded River Reuss in August 2005. A considerable quantity of large wood accumulated against the weir in Perlen (Canton Lucerne).

Dramatic video: *www.youtube.com/watch?v=ZM6Pkf5argY*

and diameter of the pieces found, it can be concluded that most of them are only a fifth of their original size. The data has been integrated into the simulation model 'Iber-Wood', which calculates the transport and deposition of large wood in rivers. It can be used, among other things, to predict where wood could accumulate on river- or gravel-banks. This wood must be monitored and removed if necessary as it might otherwise be carried away in the next flood and become a danger. *(cho)*

Photo: Swiss Air Force, DDPS

WOOD FORMATION **Watching wood grow.** When does a tree form new cells? And how do environmental conditions influence this process? WSL researchers are finding answers to these questions in wood samples from the Lötschental.

Loïc Schneider turns the wheel of the cutting machine energetically. Wafer-thin strips from a paraffin block fixed in the machine pile up on the cutting surface. Embedded in the block is an approximately one-centimetre-long drill core from the stem of a larch tree. Loïc carefully picks up a strip with his tweezers, dips it in a warm water bath and quickly fishes it out again with a glass plate to put aside to dry.

Loïc is a technician in WSL's tree-ring lab. The wood samples he is cutting come from the Lötschental valley in Canton Valais. Since 2007, WSL employees have, every week, taken small drill-core samples of larch and spruce from the trees' cambial and phloem zones, i.e. from where a tree continuously forms new cells during the growing season and thus increases in size. More than forty trees at five different elevations are currently sampled weekly. Sensors beside the trees measure the site conditions, such as the temperature and humidity of the air and soil. Other measuring instruments record how much water evaporates from the trees.

"We want to find out how the environmental conditions affect tree-ring formation and the characteristics of the wood cells, such as the thickness of the cell walls," explains Patrick Fonti, who is in charge of the investigations. Conclusions can then be drawn from the resulting data about how the wood is functioning – for example, whether the tracheids are large enough to trans-

Cutting machine for fine things: with a so-called rotary microtome, Loïc Schneider produces wafer-thin slivers of the wood cores.

Photo: Bruno Augsburger, Zurich

Each week WSL researchers take wood samples from larches and spruce above Ferden in the Lötschental.

port sufficient water from the soil to the leaves. Patrick is particularly interested in the influence of changing temperatures on the time in spring when cell formation begins. In the long term, Patrick and his colleagues hope to be able to draw conclusions about how climate change affects the growth of trees and whether trees will be able to cope with the changes in environmental conditions.

The Lötschental is particularly well suited for investigating the influence of global warming on trees because the temperature difference between the tree line and the valley floor corresponds to the predicted temperature increase of 3 °C for the next hundred years. The wood cores from different elevations can be compared to see how the differences in temperature affect tree growth. For a number of years now, Patrick and other WSL staff have travelled to Valais once a week to take samples. "It's an enormous effort, but it's worth it. We have obtained a data series with high resolution and can virtually watch the wood grow and the annual rings form." As the dendro-ecologist says: "No one has ever done this before with so many trees and over such a long period of time." This is why researchers from all over the world are very interested in being able to work with the data.

For further information about the Lötschental project, see: *www.wsl.ch/loetschental*-en

Making cells visible

Before Patrick and his team can examine the wood cores, they have to be prepared in WSL's tree-ring laboratory. This involves complex steps, and the process takes several days. Before cutting the samples, water has to be extracted from the wood. The drill cores are then embedded in paraffin. This wax-like material is solid at room temperature and is used to fix the bits of wood so that they can be cut into slivers that are just seven micrometres thick – about ten times thinner than the average human hair. The wood cells, however, remain

Photo: Patrick Fonti, WSL

intact. The micro-cuts are then stained with dye so their components can be better distinguished.

"In the past, we inspected the wood samples under the microscope and counted the cells by hand. Today the computer does that," explains Patrick. He opens a scanner that can process a hundred samples simultaneously. The machine delivers high-resolution images in which every single cell is visible. Staining the samples makes it possible to distinguish the cell components – lignin and cellulose. Special software is used for counting and measuring the wood cells and provides information about their structure.

Wood for the future

On the basis of the data evaluated so far, Patrick and his colleagues have been able to show that the start of cell growth in trees is delayed by two to three days per hundred metres elevation difference. In other words, if it is one degree warmer, the growth phase starts about five days earlier. The starting moment is relevant because this is when the tree begins to store CO_2 in its cells. This important quantity enables researchers to calculate how much carbon a tree can bind from the atmosphere (see page 10).

For further information about WSL's tree-ring lab, see: *www.wsl.ch/tree-ring-lab*

Not all the wood cores from the Lötschental have been prepared and evaluated yet. As soon as sufficient data has been processed, the researchers will be able to develop a model to predict whether a tree will be able to survive at all if it becomes massively warmer or drier. The model will take into account the site conditions in predicting how much wood the tree will form, the structure of its wood cells and what properties the wood will have. This will involve combining the researchers' data with the results from classical tree-ring research.

Patrick is particularly curious about the samples from the hot summer of 2015, which left its mark in the wood. "We want to find out how the extreme dryness has affected the structure of the wood." The data will be evaluated in 2020. *(lbo)*

Photo: Bruno Augsburger, Zurich

Jasmine Zollinger, Davos

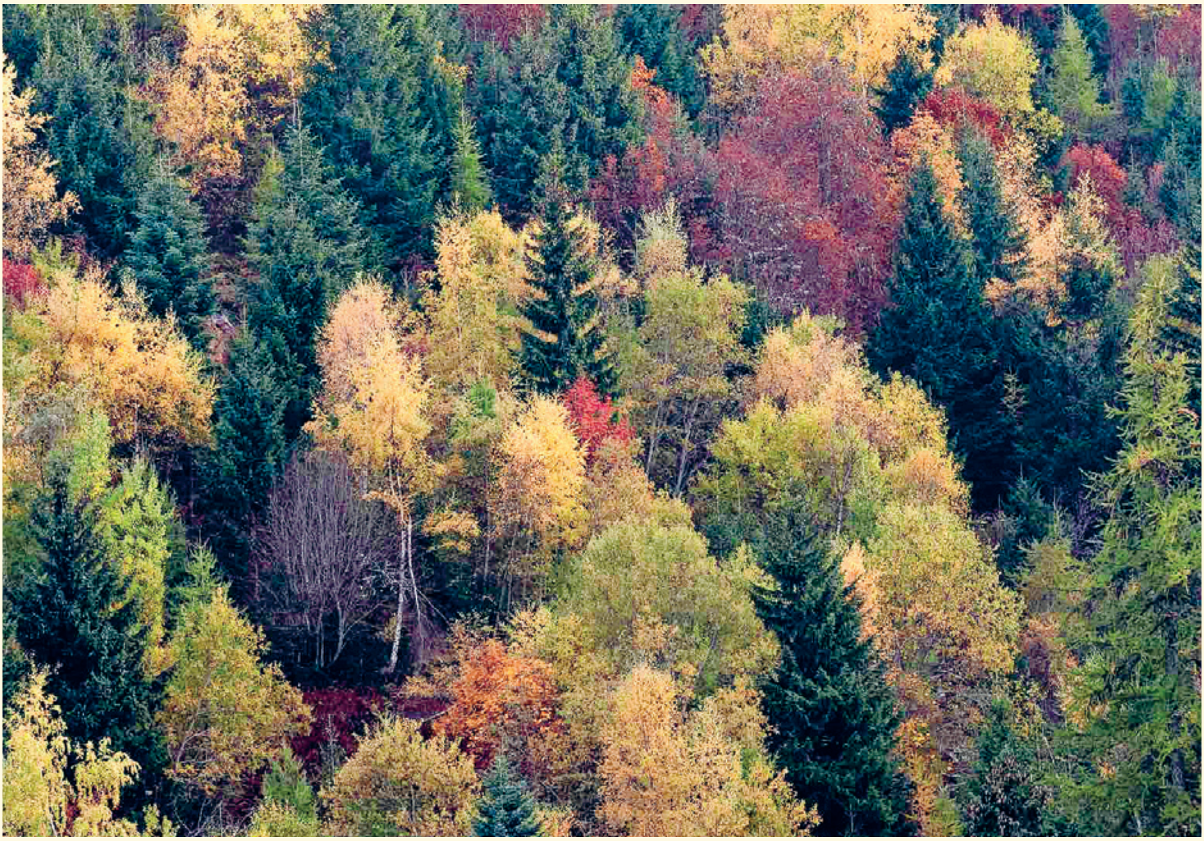
“What fascinates me about golf is how you play against yourself. Once I was about to throw my golf iron into the Albula because it didn’t work as I wanted. Then an experienced golfer told me: ‘Golf teaches you humility.’ How right he was!”

PERSONNEL MANAGER WITH HEART

As a child Jasmine Zollinger wanted to become a marine biologist. Today, she is very happy with her job as head of HR at SLF. It involves hiring employees and looking after them until they leave. She enjoys working with people who have different professional and cultural backgrounds, as well as diverse personalities and views. She is glad to be able to support her colleagues at SLF, which also includes providing advice in the event of interpersonal conflicts.

FOREST

National Forest Inventory: The forest area is increasing and forests are becoming more diverse



A forest rich in tree species on Col de la Forclaz (Canton Valais).

Almost a third of Switzerland's territory is covered with forest. The National Forest Inventory (NFI) monitors how the trees are doing. After nine years of fieldwork and intensive data analysis, the results of the fourth survey, which was conducted from 2009 to 2017, are now available.

The analyses show that the forest area has increased by 2.4 percent since the last survey. The wood stock has also increased, with 13 million cubic metres more wood in the forest today than eight years ago – a volume equivalent to over 5000 Olympic swimming pools. The increase has taken place mainly in the Alps and on the southern slopes of the Alps. On the Central Plateau, on the other hand, the wood stock has continued to decline as more wood is used here than regrows.

The quality of the forest as a habitat for animals and plants has increased significantly. The forest has become richer in structure and more diverse with, in particular, a larger number of woody species on the NFI plots. "But this diversity is not only positive," says Urs-Beat Brändli, long-standing head of the Scientific Service in the NFI programme at WSL. Among the woody plants are also some introduced shrub species, such as buddleia or hemp palms, that are invasive and can displace native plants. Urs-Beat says: "We will take a closer look at these problem species in the next survey and document their spread."

Photos: Simon Speich, www.speich.net; WSL

According to the NFI, 42 percent of the forest area serves primarily as protection forest for residential areas and traffic routes. “The protective effect of the forest against natural hazards such as rockfall or avalanches has improved slightly since the last survey, and the stands have become somewhat denser,” says Urs-Beat. Whether this will continue to be the case in the future, however, is uncertain: in around a quarter of the protection forests the regeneration is insufficient, which means not enough young trees are growing.

“The large numbers of roe deer, red deer and chamois could be to blame for this,” says Urs-Beat. In the case of the silver fir, which plays an important role especially in protection forests, the browsing rate in young forests has more than doubled within the past twenty years. In addition, maintaining the forest, i.e. promoting forest rejuvenation and stand stability, is difficult in these areas as only just over a third of the protection forests have well-developed forest roads for management.

Valuable data for Switzerland

WSL has been carrying out the NFI since the 1980s in cooperation with the Federal Office for the Environment. Before the data is evaluated, assessments are made in the field. These inventories are hard work for the survey teams. For the fourth NFI, they visited more than 6500 sample plots, evenly distributed throughout Switzerland. They surveyed more than 72,000 trees, some of them in very steep terrain. As a result, the NFI contains statistically reliable information on the condition of the forest, which is valid for the whole of Switzerland.

The most important results of the NFI4 have been published on the Internet in the form of tables and maps. They are explained and placed in their current context in a book, which can be ordered from WSL with a charge to cover postage costs. By

High game populations, e.g. of deer, have led to more browsing in young forests.

The results of the fourth National Forest Inventory have been summarised in book form.

no means all the data from NFI4 has been analysed. The data is available for further analysis on request for research and practical purposes. Meanwhile, the monitoring continues: the NFI5 surveys already started in 2018.

(lbo)

www.lfi.ch

Drawing cover: Ingo Giezendanner, GRRRR, Zurich

LANDSCAPE

Satellite images show how grasslands are being managed

On Swiss maps, agricultural areas are left blank. The reason for this is that nationwide information on, for example, how these 'white areas' are managed, is missing. WSL researchers can now fill this information gap for grasslands thanks to state-of-the-art satellite technology.

Satellite images of the area around Bözen (Canton Aargau) acquired on 7 June (top) and 16, June 2019 (centre). The differences between them are highlighted in the bottom image: mown meadows are shown in dark blue, and others where the grass has grown in light green.

For this work, the geo-computer scientist Robert Pazur and his colleagues used data from, among other things, the PlanetScope satellite constellation. These satellites provide images in the visible and near-infrared spectrum with high temporal and spatial resolution, producing daily imagery with an accuracy of three metres. Robert automated the interpretation of the images, and used the computer to measure the gradations in the 'greenness' of the fields in the images. In this way, he was able to show differences before and after mowing a field, when an area had been fertilised or how intensively it was being grazed.

Canton Aargau was chosen as the region to test the new method because large areas are used for agriculture – some very intensively and others extensively. This results in a heterogeneous mosaic covering all stages of grassland use. In addition, the canton collects general data on farm management, such as which areas are grazed and which are used to produce hay. "This information enabled us to confirm that the results from the automated image interpretation are plausible," explains Robert.

Data collection is easier

Knowing how grassland is managed is important, for example, for planning biodiversity protection measures. Elements for improving connectivity, such as hedges linking two protected areas, should ideally be included in less intensively used areas. The analyses of the satellite images can now be used to support such planning.

Photos: PlanetScope/WSL

The new method could also be relevant for biodiversity payments in agriculture. Today, payments are largely based on information provided by the farmers themselves, who have to report on their activities. In future, satellite images could facilitate the collection of relevant data and input. The method needs, however, to be further tested and improved. *(lbo)*

LANDSCAPE

Making climate policy visible at the click of a mouse

Whether heat waves in cities, heavy rain with floods and landslides or the emergence of new diseases, people must adapt to the effects of climate change. The transnational EU project 'GoApply' has collated what policy-makers in seven Alpine countries are doing about it and how they coordinate these activities. For people interested in having a quick overview of the various regulations, measures and actors involved in climate adaptation, WSL researchers have compiled them in an interactive website.

For example, if you click on Switzerland and its action plan for the 'National Adaptation Strategy', you will see lines radiating out like a spider's web that link the offices involved and the numerous pilot projects. These include, for example, urban development in Sion in Canton Valais adapted to heat and heavy rainfall, as well as a grassland insurance for farmers in the event of extreme drought. Very few lines lead to local or cantonal actors, which indicates low local participation. "The web tool highlights the strengths and weaknesses of individual approaches," says WSL's project manager Marco Pütz. It can be used to identify opportunities for action and to set priorities for adapting to climate change. *(bki)*

With the interactive website 'GoApply', you can find out about current climate projects and actors, as well as how they are linked.

www.wsl.ch/gov-vis-cca

Alpine plants and climate change: Which genes help them adapt?

Underway in all weathers: the researchers used GPS to determine the sites where the plants were growing and collected leaf samples for genetic analyses.

Climate change is giving alpine plants a hard time: their habitats are changing dramatically because it's getting warmer. How well plants can adapt to the new conditions depends on their genetic make-up. Some individuals in a population may have genes or gene variants that help them conquer new habitats. So far, however, little research has been done on how genetic diversity is related to specific site conditions.

To investigate this topic, the doctoral student, Aude Rogivue, and the senior scientist, Felix Gugerli, from the 'Ecological Genetics' Research Group at WSL, have focused on the alpine rock cress *(Arabis alpina)*. It is an undemanding plant that also grows high up in the mountains on sites that may vary greatly within a few metres – from sunny to shady, cold to warm and moist to dry. "Our aim was to find differences in the genetic make-up between closely related individuals exposed to very different environmental conditions," says Aude. This would contribute to understanding which gene variants help plants adapt to climate change.

In collaboration with the Swiss Federal Institute of Technology in Lausanne and the Universities of Neuchâtel and Berne, the researchers determined the complete genomes of 300 alpine rock cress specimens. These were growing in four study sites in the Vaud Alps near Les Diablerets at altitudes between 2000 and 2500 m above sea level. The researchers produced a high-resolution digital terrain model of the study areas using LiDAR images Canton Vaud provided (LiDAR is a laser-based method for measuring distances). From the model, they then derived

Photos: Aude Rogivue, WSL

ecologically relevant information about the sites where the plants they analysed were growing. They also measured temperature and air humidity on site with probes.

From these measurements, they obtained a huge data set – the first in this form. Its evaluation is well underway. “So far we have not been able to identify a clear trend,” says Felix, although they have found some differences in the genes for general metabolism or reproduction among the plants they analysed. The function of many other genes is, however, still unknown, which makes it difficult to detect meaningful associations with environmental conditions. The data set is nevertheless useful for investigating other questions in population genetics and is freely available to other research groups. *(cho)*

www.wsl.ch/genescale-en

The Alpine rock cress *(Arabis alpina)* grows on different terrain including rocks and scree.

BIODIVERSITY

Rare plants thrive in nature reserves, but are not yet protected enough

They have names like star swertia, tufted milkwort or English sundew, and grow on fens, bogs or species-rich dry grassland. The size of the areas with these nutrient-poor habitats have shrunk by around ninety percent in Switzerland due to the intensification of agriculture since the beginning of the 20th century. Today, most of the remaining remnants are specially protected to conserve the highly specialised species.

A team of WSL researchers wanted to find out how well such nature conservation areas actually do protect rare plants. Nina Dähler, a Master’s student, therefore analysed data from three existing surveys, where the occurrence of rare plants within and outside protected areas was re-examined after an initial survey. She focused on species typical for mires and dry grasslands. Her data sources were the data-bases for the revised Red List of vascular plants, the Monitoring the Effectiveness of Mire Protection programme and a survey of target species in dry grasslands in Canton Schaffhausen.

Displaced by common species

Only one in two wetland species and two out of three grassland species could be found in sites where they had previously occurred. The propor-

Photo: Aude Rogivue, WSL

Rehhagweid a protected dry meadow in Canton Basel-Land near Langenbruck.

tion is, however, larger in areas that contained more protected sites. The researchers therefore conclude that protected areas generally increase the survival of rare species. "But conservation target species are disappearing even from protected sites, as we have seen for mires, for example," says Ariel Bergamini, head of WSL's Research Group 'Ecosystems Dynamics'.

Lost bog species, such as the silvery sedge or the lesser spearwort, need more light and less nutritious, wetter conditions than common species. "Plants from nutrient-poor locations are often competitively weak," says the biologist. 'Everyday species', such as cocksfoot grass or the meadow fescue, grow better and faster, taking the light away from the specialists. The decline of the rarer species suggests that too many nutrients are still entering the protected areas. This could, Ariel thinks, be caused by overgrazing or irrigation, or by excessive inputs of nutrients via the air.

The Schaffhausen data is, however a source of hope. There the majority of the 26 dry grassland species relevant to nature conservation have not declined since the 1990s. Only four have become rarer, and eight have even become significantly more common. "Protection of dry grasslands works well if they are properly looked after," says Ariel. Late mowing allows rare plants to multiply, and extensive grazing prevents shrub encroachment.

One central problem is that the protected areas are often rather small and the sites far apart. This makes it more difficult for plants to spread and increases the risk that some species will become locally extinct. Ariel therefore also believes it could be a sensible option to reintroduce target species under certain conditions – similar to the re-establishment of animal species, such as the bearded vulture. *(bki)*

biotopschutz.wsl.ch/en

Photo: Ariel Bergamini, WSL

BIODIVERSITY

Endangered habitats for mosses and ferns: Erratic boulders on the Swiss Plateau and in the Jura

Among the characteristic calcareous rocks of the Jura and Swiss Plateau, you will occasionally encounter erratic boulders – large rocks carried down from the Alps by glaciers during the last Ice Age. Unlike the rocks around them, they often consist of silicates, serving as a kind of oasis for some plants, which can only survive on non-calcareous rock.

The biologist, Daniel Hepenstrick, who is a researcher at the Zurich University of Applied Sciences and a doctoral student at WSL, is studying the mosses and ferns that occur on such erratic boulders. "Most of the species we have found are not rare, but regionally they occur exclusively on these boulders." Daniel would therefore like to raise people's awareness of these erratic boulders as habitats that are worth protecting.

Coexistence is possible

In the past, the hard blocks of rock were popular as mini quarries for building material. Today, the threat from humans is more indirect: for example 'cleaning', i.e. removing vegetation for climbing and bouldering.

Climbers also powder their hands with magnesia, which is chemically related to lime, to get a better grip on the rock. Laboratory tests have, however, shown that even small traces of magnesia can impede the germination of typical moss species.

Daniel does not see having a general ban on climbing as a solution, but rather recommends having separate zones on the boulder. The most valuable areas for plants could then be protected. *(bio)*

Taking a close look: Daniel Hepenstrick (left) and René Amstutz from Pro Natura examining the moss species on a boulder.

Photo: Michel Lüthi, bilderwerft.ch

Studying snow helps 'read' ice cores

Taking samples at the Weissfluhjoch test site above Davos. To avoid contaminating the snow samples, the researchers wear protection suits and face masks.

Analysing the various particles embedded in ice cores from the polar caps or mountain glaciers helps to reconstruct the climate of the past. Ions, such as ammonium and calcium, or trace elements, such as iron and lead, indicate air pollution from, for example, forest fires or volcanic eruptions. Oxygen isotopes, on the other hand, provide information about earlier temperatures.

When interpreting the results, however, you need to take into account how the particular substances got into the ice in the first place, namely through the snow where they were initially deposited. It then took years or even decades for the snow to turn into ice. "A lot can happen during this time," says Jürg Trachsel from SLF. The snow cover and thus the distribution of the embedded particles change due to the exchange of air with the atmosphere, transformation processes in the snow – so-called snow metamorphism – as well as melting events. "This can lead to the original composition of the ice cores changing and a redistribution or loss of the embedded particles," says Jürg.

Marked changes

In his doctoral thesis, Jürg therefore investigated, together with researchers from the Paul Scherrer Institute (PSI) in Villigen, the influence of transformation processes on the isotopes, ions and trace elements in snow. This involved taking snow samples in the field in winter 2017 and carrying out parallel experiments in the cold laboratory at SLF in Davos. They found that the distribution

Photo: Julia Wessels, SLF

and concentration of impurities can change significantly within a few weeks or months.

Although the trace elements they analysed remained stable over the winter, some were washed out with the onset of snowmelt. The ions showed the same pattern: while some disappeared almost completely with the meltwater, others, such as ammonium and fluoride, remained. This is due to snow metamorphism, which embeds these ions deeper into the ice structure. Metamorphism and meltwater also influence the isotope concentration.

"This means that the uncertainties involved in interpreting ice cores are greater than previously assumed," says Jürg. The study has identified which ions and trace elements are preserved best. This information will become increasingly important for the analysis of ice cores in future because global warming means that glaciers at higher elevations are also increasingly exposed to temporary thawing phases that affect what remains embedded in the ice. *(cho)*

http://tiny.cc/rb2dlz

SNOW AND ICE

Observing glaciers: When extreme years become normal

Matthias Huss, people have been monitoring glaciers in Switzerland for over a hundred years. Do we really still need to monitor them?

MH: Yes. We need measurements to find out what's happening to the glaciers, as well as to look into the future and to develop simulation models. The measurement series is becoming more valuable the longer it gets!

Why do we need researchers for this?

MH: The monitoring required is actually a skill. In some cases, helpers are involved. Traditionally, most of them have been foresters. Many measurements are still made using the same methods as always. For example, we still measure glacier melt with poles drilled into the ice. But we also use modern technology – aerial photographs and GPS have largely replaced the measuring tape, and we use laser scanning and photogrammetry to determine changes in volume. It is the scientists who develop such techniques. And for me, being outside and experiencing the changes directly gives me lots of ideas for research.

The Gries glacier in the Valais Alps in August 2003 (top) and September 2018 (bottom). It has receded greatly in just fifteen years.

Photo: Simon Oberli, GletscherVergleiche.ch

Last autumn the Pizol Glacier was declared dead. Why do you continue to study it anyway?

MH: We removed the Pizol Glacier from the monitoring network because it had become too small. But there is still ice around. No one has ever documented the disappearance of a glacier right up to the bitter end, which is why we are still taking measurements. For example, if the ice is increasingly melting, and at the same time breaking up and becoming covered with debris – what happens next? Do forms of permafrost such as rock glaciers gradually develop? We have no answers to such questions, although there are many similar cases in Switzerland.

So you are accompanying glaciers in their 'death throes'. Isn't that rather depressing?

MH: It may seem depressing from the outside, but I find it fascinating seeing something happen. I am a researcher, after all, and find things that change raise questions, which is exciting.

Looking to the future: will your grandchildren still experience glaciers in the Alps?

MH: It's incredible how quickly the glaciers are currently losing ice. In the past, years with a lot of melting did occur – but the past four years have all been extreme! Glaciers are too big for the current climate and are trying desperately to adapt and find an equilibrium by melting. Even if climate protection is implemented very quickly and comprehensively worldwide, the glaciers my grandchildren will see will therefore have only around a third of the current glacier volume. Many smaller glaciers will have disappeared, and long glacier tongues reaching down into the valleys will no longer exist.

Could technical measures save the glaciers rather than leaving them to 'die'?

MH: Covering snow and ice in summer works well for small areas. A white fleece cover significantly reduces melting and preserves important sections of ski slopes. But this method cannot be used for entire glaciers because it is too costly and environmentally problematic. A recent idea for the Morteratsch glacier is to cover it with artificial snow so that more ice can build up. Theoretically, this could work if we assume a climate scenario with low warming. The crux of the matter is that it requires a lot of water, and the water would be needed in winter. So large reservoirs would have to be built, which would be very expensive and difficult to implement.

So there's no quick technological fix?

MH: No, only locally. If we want to save the glaciers, we must protect the climate.

www.glamos.ch/en

Matthias Huss is a glaciologist at WSL and head of the Swiss glacier monitoring network GLAMOS.

Photo: Gottardo Pestalozzi, WSL

Photo: Bruno Augsburger, Zurich

Tamaki Ohmura, Birmensdorf

"I like to take the longer route through the forest when I cycle to work. I usually stop near this clearing to take in the atmosphere for a moment. It's a beautiful place to observe the changing of the seasons."

SOLUTIONS FOR FORESTRY

Is it better to use the wood or to leave the trees standing and get an income from selling CO_2 certificates? This is just one of the potential goal conflicts forest owners face today. In the ATREE project, the political scientist Tamaki Ohmura is analysing political instruments to solve such conflicts. Possible solutions include regulation or economic incentives, such as the creation of a market for CO_2 certificates.

Preparing better for the future: Learning from avalanche winters

During the 20th century, the most disastrous avalanche winter in the Swiss Alps was in 1950/51, when 98 people were killed and around 1500 buildings destroyed. As tragic as such events are: "Every avalanche winter of the last 150 years has contributed to improving avalanche protection," says Stefan Margreth, head of the 'Protection Measures' Research Group at the WSL Institute for Snow and Avalanche Research SLF. The winter of 1951 also led to a paradigm shift: until then, the protection structures in avalanche starting zones had consisted mainly of massive walls and terraces. However, it became apparent that these were not effective enough. Consequently, using steel, concrete and aluminium to construct supporting structures was promoted tremendously. Researchers at SLF were involved in testing various types of construction and building materials. In addition, slopes with protection forests were reforested and the avalanche warning system was improved.

The avalanches of the winter of 1951 also claimed several buildings that had only recently been built. The first hazard maps were produced in order to be able to exclude avalanche-prone zones in land-use planning in future. The avalanche winter of 1968, during which many exceptionally large avalanches occurred, was decisive for improving and standardising the hazard-mapping procedure further. By far the most damaging avalanche was the 'Dorfbach' avalanche in Davos, which claimed four lives and destroyed 29 buildings. Although a hazard map existed for the affected area, it only took into account the size of avalanches that

One hundred percent safety from avalanches is an impossible goal. In January 2019, a powder snow avalanche caused major damage on Schwägalp (AR).

Photo: Stefan Margreth, SLF

could be expected to occur about every 50 years. Afterwards SLF developed standardised criteria for producing hazard maps. These take into account extreme avalanches with a return period of up to 300 years.

Interplay of various measures

Extreme avalanches also occurred in the winter of 1999. Long and intensive snowfall cut off valleys and villages from the rest of the world for up to two weeks. Around 1200 avalanches came down causing damage and a total of 17 fatalities. At SLF the events were analysed in detail. “The analysis showed that the structural avalanche protection had worked well,” says Stefan. Overall, the combination of structural measures with planning (e.g. avalanche hazard maps), biological (protection forest) and organisational measures (e.g. closures) contributed greatly to preventing even more serious damage. This so-called integral avalanche protection has been further improved since 1999. The event analysis did, however, also uncover some inadequacies in the local avalanche services, and training has subsequently been promoted more.

The avalanche situation in January 2018 was a test for integral avalanche protection: for the first time since 1999, the SLF avalanche warning service forecasted that the highest danger level 5 would be widespread. However, although 150 avalanches occurred that caused damage, there were no fatalities or major damage in residential areas during the 2018 avalanche winter. “Luck may have played a role in this,” says Stefan. In addition, snowfall and avalanche activity were less extreme than in 1999, but “the developments and measures for integral avalanche protection proved their worth and were decisive.” This was confirmed by the event analysis that SLF conducted afterwards for the Federal Office for the Environment.

In January 2018, the avalanche in the Jungbach near St. Niklaus (VS) narrowly missed some agricultural buildings.

A new challenge in the future will be the influence of global warming on avalanche activity. Processes such as a strongly fluctuating snowfall line with rain up to high elevations or glide snow avalanches could become more frequent and make it necessary to adapt protection measures. Stefan is convinced that: “Further research is urgently needed so that we can be best prepared for future events.” *(sni)*

Photo: Stefan Margreth, SLF

Photo: Bruno Augsburger, Zurich

Marco Ferretti, Birmensdorf

"After an intense day at work, it's good to relax in the Café Bar 'Nordbrücke' in Zurich Wipkingen and drink a good espresso or meet friends in the evening. I really like the village atmosphere there in the middle of Zurich."

UNDERSTANDING HOW THE FOREST CHANGES

Marco Ferretti is head of the Research Unit 'Forest Resources and Forest Management' and chairs the international forest monitoring programme ICP Forests. For him, synergies between the different types of forest monitoring are of strategic importance. "Long-term monitoring is a goldmine for research. Combining such data can help us better understand how environmental changes affect the vitality of our forests."

OUTLOOK, DIAGONAL NO. 2, 2020

Extremes fascinate us. Whether it is research at the North Pole in unimaginably cold conditions, extraordinarily hot summers with drought and forest fires, or creatures able to survive in the most inhospitable places – all are interesting. Researchers at WSL are investigating how the natural world and humans react to extraordinary environmental events – and sometimes themselves also get into extreme situations.

Photos: Gottardo Pestalozzi, WSL

SUBSCRIPTION SERVICE

Diagonal can be ordered free of charge: www.wsl.ch/diagonal

For single copies, contact:
Swiss Federal Research Institute WSL
Zürcherstrasse 111
CH-8903 Birmensdorf
eshop@wsl.ch

IMPRINT

Publisher:
Prof. Dr. Konrad Steffen, WSL Director

Text:
Lisa Bose (lbo), Claudia Hoffmann (cho), Beate Kittl (bki), Sara Niedermann (sni), Birgit Ottmer (bio)

Editorial management:
Lisa Bose, Claudia Hoffmann; diagonal@wsl.ch

Translation: Silvia Dingwall, Nussbaumen

Design:
Raffinerie AG für Gestaltung, Zurich
Layout: Sandra Gurzeler, WSL

Printing: cube media AG, Zurich
Paper: 100 % recycled

Circulation and frequency of publication: 400, twice a year

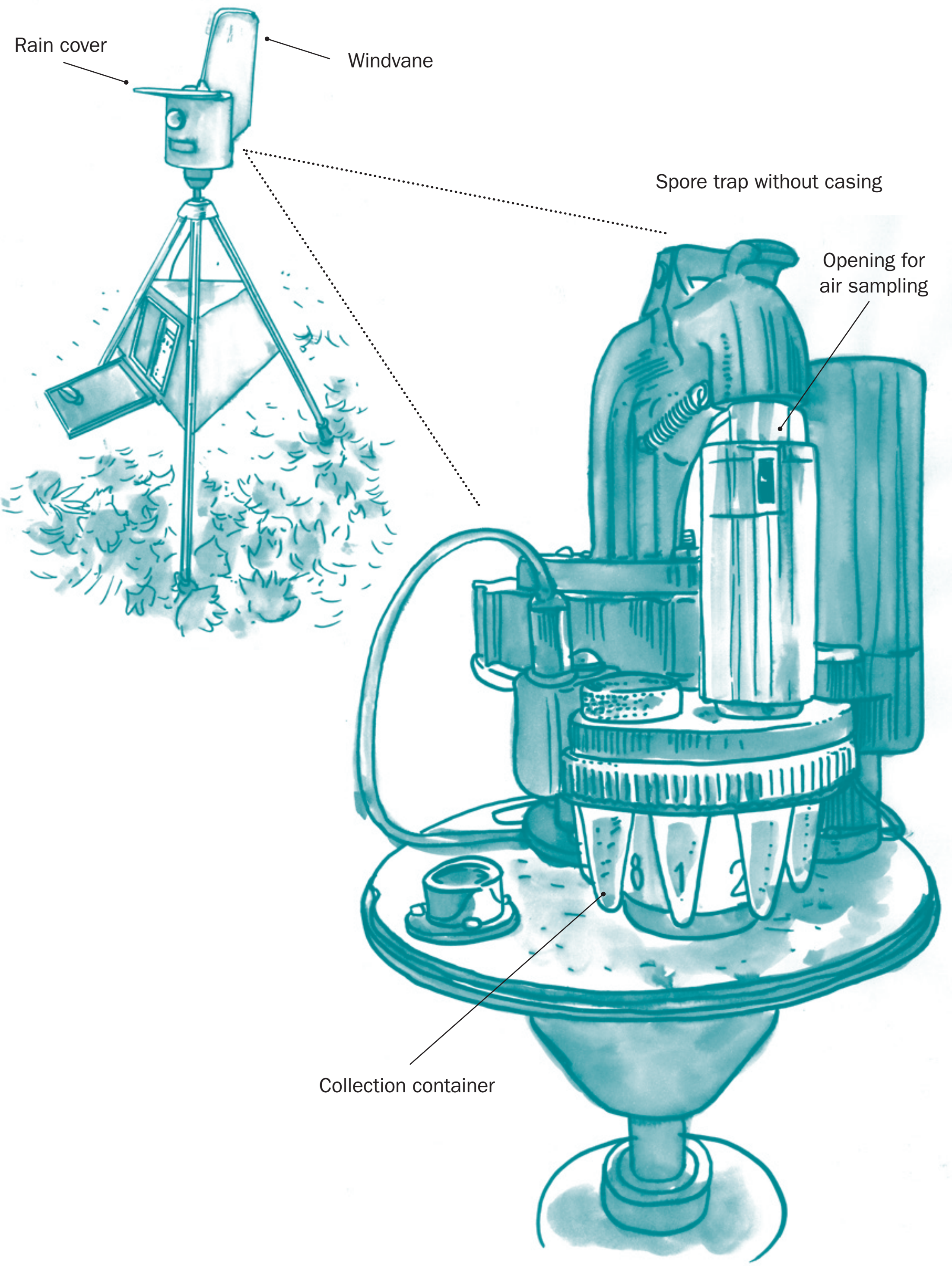
The WSL magazine Diagonal is also published in German and French.

Cite as:
Swiss Federal Research Institute WSL, 2020: WSL magazine Diagonal, 1 / 20. 36 pp., ISSN 2297-6175

PEOPLE

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

SPORE TRAP



The spore trap sucks in air from the environment constantly, collecting the particles it traps, which include spores from fungi, in a small container. The spore samples are analysed genetically to determine the species they come from. The trap on the WSL site in Birmensdorf is part of the Global Spore Sampling Project. Up until now, only 150,000 species of fungi have been scientifically described, but it is assumed that there are actually between two and 13.2 million. The sampling project should help to obtain more accurate estimates.

Video at:
www.wsl.ch/object

Illustration: Raffinerie; Cover: Julia Wessels, SLF

Worth protecting: moss flora on erratic blocks, p. 27

Embedded particles: Traces of climate history in snow, p. 28

LOCATIONS

Birmensdorf
Eidg. Forschungsanstalt
für Wald, Schnee und
Landschaft WSL
Zürcherstrasse 111
CH-8903 Birmensdorf
Phone 044 739 21 11
wslinfo@wsl.ch
www.wsl.ch

Davos
WSL-Institut für Schnee- und
Lawinenforschung SLF
Flüelastrasse 11
CH-7260 Davos Dorf
Phone 081 417 01 11
contact@slf.ch
www.slf.ch

Lausanne
Institut fédéral de
recherches WSL
Case postale 96
CH-1015 Lausanne
Phone 021 693 39 05
lausanne@wsl.ch
www.wsl.ch/lausanne

Cadenazzo
Istituto federale di
ricerca WSL
Campus di Ricerca
a Ramél 18
CH-6593 Cadenazzo
Phone 091 821 52 30
info.cadenazzo@wsl.ch
www.wsl.ch/cadenazzo

Sion
Institut fédéral de
recherches WSL
c/o HES-SO
Route du Rawyl 47
CH-1950 Sion
Phone 027 606 87 80
valais@wsl.ch
www.wsl.ch/sion

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 SLF