CLIMATE CHANGE

Quo vadis, Flora? Climate change is altering habitats. How will the plant world respond? WSL researchers are using computer models to try to find out.

Will our children's children find themselves walking in winters in Switzerland under evergreen holm oaks or olive trees? It may sound bizarre, but average temperatures are rising, the summers are getting hotter, the winters wetter, dry periods longer and heavy precipitation more frequent. Habitats change with climate, opening up new opportunities for some plants to spread and putting others under pressure.

Researchers at WSL are working on understanding these processes and predicting the future responses of plants. They use computer programmes to model where, for example, alpine plants might grow in future, or how well trees are adapted genetically to the climate conditions that are forecasted. Such future projections make it possible to prepare forests for the future climates and to protect endangered plants. This is in line with the UN's Sustainable Development Goals (SDGs), which stipulate that, in addition to protecting terrestrial ecosystems and biodiversity, "urgent action must be taken to combat climate change and its impacts."

So what will grow where in future? To answer this question, reliable climate models are needed. Niklaus Zimmermann, a researcher at WSL, describes one simple comparative method like this: "If you know what kind of climate conditions can be expected for a particular region in a hundred years, you can look for places that already have such a climate." He continues: "You can then go there and analyse the plant communities that grow at these sites."

This was the approach taken a few years ago in the 'Forest and Climate Change' programme of WSL and the Federal Office for the Environment. The team was led by Peter Brang, a forest researcher at WSL, who died in July 2022. The researchers identified regions on the European mainland where the climate today corresponds roughly to that predicted for Geneva, Basel or Chiasso in a hundred years time. If a warming of 6 degrees takes place – which is the most extreme of the climate scenarios considered – comparable regions for Geneva would be the Maremma and central Italy; for Basel, southern France and the eastern Po Valley; and for Chiasso, along the Adriatic coast and in Tuscany. Forests there are often evergreen.

Slow movers

But that does not mean that a Mediterranean forest will, in future, grow on Switzerland's Central Plateau because there are obstacles like the Alps in the way. Moreover, trees migrate very slowly. Even the very fastest species, such as poplars or birches, which grow quickly and whose seeds are dispersed by wind, manage to travel without human intervention only one kilometre per year. "But the model gives foresters, for example, indications as to which tree species they could try planting for the forests of the future," says Niklaus.

He is using so-called habitat suitability analyses to address the question of where species are likely to find suitable habitats in future. "Putting it simply, you first examine the climate conditions under which a species thrives today," he explains. "And then you calculate where the same conditions will prevail in the future." Dynamic models, which are much more complex, also show the routes along which the distribution areas could shift and identify possible obstacles to migration.

However, if a simple model that relies on statistical methods indicates that the beech will no longer find a suitable climate on the Central Plateau in a hundred years, this does not mean that it will disappear everywhere in this area. If no dramatic and extreme events occur – such as several long periods of drought in a row – plants can still survive for centuries in habitats that are no longer suitable for them. "This is known as 'extinction debt'," says Niklaus.

In a joint study of WSL and the University of Vienna, researchers found that sixty per cent of the more than one hundred alpine plants they investigated were living with such an extinction debt. These species were growing at the lower edge of their actual ranges in habitats where, according to the models used, they should actually no longer occur. "So such models do not predict facts. They merely indicate what may potentially happen," Niklaus explains.

Genetically equipped for the future?

These modelling approaches may be overestimating extinction debts under climate change. For example, they often assume that only one habitat is optimal for an entire species. In reality, however, the levels of tolerance species have for

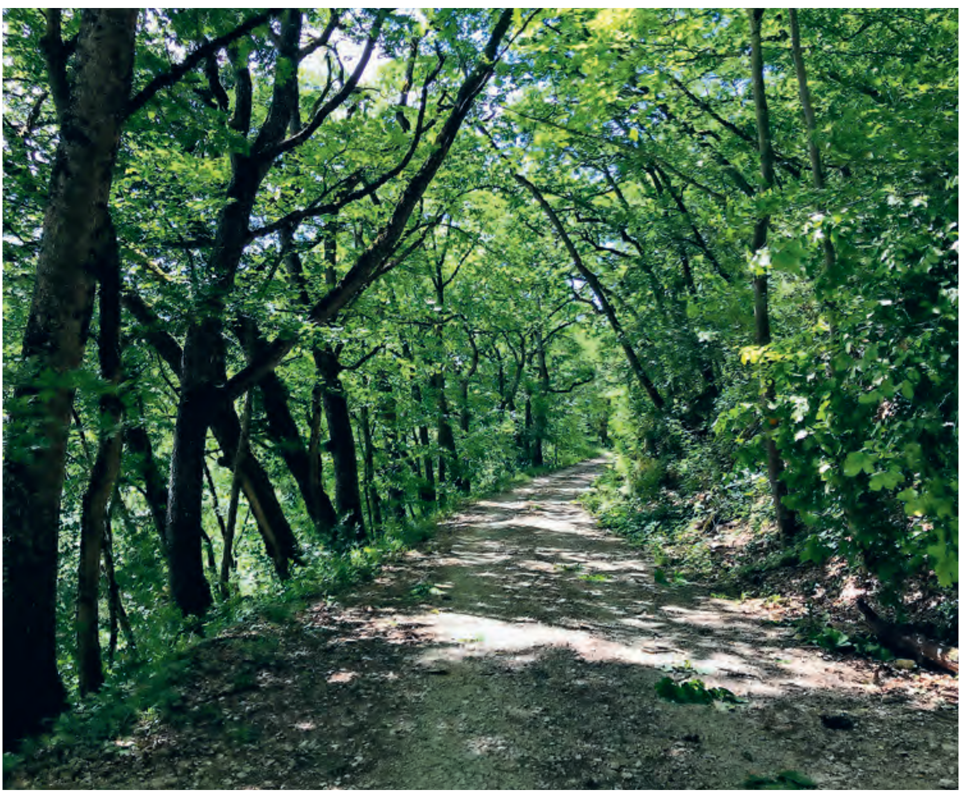

Photo: Christian Rellstab, WSL

According to species distribution models, the thermophilic and largely drought-resistant oaks are considered possible beneficiaries of climate change. However, populations may differ genetically and thus be adapted differently to future conditions.

the local site conditions may well vary from population to population. For example, their minimum water requirements may be different. Moreover, these models ignore the fact that – given enough time and sufficiently large genetic diversity – species can adapt over generations to changing conditions.

To address these issues, researchers are trying out new methods in which they model the ideal future composition of populations on the basis of genetic data and climate forecasts. "This involves first determining the current genetic composition of populations using many different sites in the genome," explains Christian Rellstab, a researcher at WSL. The geneticist was one of the first – in 2016 – to try out such a method on oak trees.

After characterising the genetic variation, the researchers then identify those sites that co-vary with climatic factors, for example those where the populations that grow in cool areas differ from those growing in warm locations. For their analyses, they therefore need genetic data from plants that grow in geographical regions or periods with different climates, such as from old trees that had germinated and established under different climatic conditions. This was also the approach taken in a recently published WSL study on Swiss stone pines. The team, led by Benjamin Dauphin, Christian Rellstab and Felix Gugerli, found that more than one hundred sites in the trees' genomes were related to the temperatures of the locations where they grew. And the number of genetic sites related to precipitation was even as high as several hundred.

Based on such data, the model then calculates which genetic composition would be suitable for a future climate. The further away the current genetic state of a population is from the optimal state in the climate future, the greater the risk of it not being adapted one day. Such information is helpful for protecting biodiversity: "If you want to save a species, you could, for example, give priority to protecting those existing populations that have the least risk of being poorly adapted and thus have the greatest chance of survival," says Christian.

The results are also relevant for forestry. For example, Christian's oak study, published in 2016, found that the Pedunculate oak was at most risk of being poorly adapted if the climate becomes drier and at least risk if it becomes warmer. This reflects the fact that the species already grows in warm and humid areas in Switzerland. The extent of the risk varied, however, from population to population. Foresters can use this information to select, for example, populations for seed production that are likely to be particularly robust in a future climate.

Valuable information

Like the habitat models, the genetic models do not take into account all the relevant factors. They are limited, for example, to present-day genetic variation. But populations can obtain new genetic variants that may be favourable through, for example, gene flow with other species or even crossing with closely related species.

The combination of these modelling approaches provides valuable data that will help to find the best ways to react to climate change and to protect the ecosystem services of forests (see graphic on page 5), as well as biodiversity, as required by the SDGs. Nevertheless, the researchers still cannot do with-


The yellow mountain saxifrage *(Saxifraga aizoides)* is one of the alpine plants that will have to move to higher altitudes to cope with climate warming.

out experiments in the laboratory and experimental gardens, or without test plantations. Such experiments are often time-consuming and expensive, but they provide important comparative data and 'reality checks' for the computer models. *(kus)*

Photo: Niklaus Zimmermann, WSL