



The forests of the future ...

- ● ● need different trees.
Researchers are working out which ones.

By Jan Schwenkenbecher

The air is hot and dry, the sandy soil cannot retain water: few forests in Germany are in worse shape now than Frankfurt City Forest. This makes it the perfect place for Wolfgang Brüggemann and Vera Holland to study climate-resilient tree species: the trees that do well here despite climate change are the ones that will survive anywhere.

Wolfgang Brüggemann and Vera Holland walk along the gravel path into Frankfurt's City Forest for just a few minutes before heading off into the undergrowth. Twigs and leaves snap and crunch under their hiking shoes. Far above their heads, clouds drift by, keeping their rain to themselves again today as so often. The sight of the clouds drifting across the sky perturbs Brüggemann, a professor of the ecophysiology of plants at Goethe University's Institute of Ecology, Evolution, and Diversity. »When you stand under an intact tree«, Brüggemann says, »you can't see the sky at all because the foliage is so dense.« He explains that healthy trees fill every gap and use every available ray of light for photosynthesis. »The damage we see here is massive«, the ecophysiologicalist says, pointing to the gnarled, leafless treetops. »We call that ›crown transparency‹. They are all doomed to die.«

On this Tuesday morning in late summer, Wolfgang Brüggemann and Vera Holland, who is also a plant ecophysiologicalist in Brüggemann's research group, make their way through the City Forest and to follow them is to take a small journey through time. When they come to one of two half-hectares of fenced-in land, Brüggemann pushes the gate open and steps into the future or, to be more precise, the »future forest«. That is what he and Holland call this little grove of trees in the middle of the forest where they have planted their own trees – trees that differ from those found elsewhere in the forest. They want to find out which trees could thrive here even as climate change causes conditions to become even more extreme. They have to hurry, though, for this future seems to be coming ever closer.

Nearly all the trees in the City Forest are sick

This is obvious in Frankfurt City Forest, which is already in extremely poor condition. Specialists use crown transparency as a measure of tree health. Many of the treetops in the City Forest are already quite transparent, and 97 per cent of the trees are visibly damaged – some more, some less.

Why is the City Forest in such trouble? »I cannot remember a time when it was this dry«, says Wolfgang Brüggemann. »2003 was bad«, he continues, »but that was just a single year. The last three years in a row – 2018, 2019, and 2020 – were all very dry.« This is especially obvious when one looks at a few 500-year-old oaks on the periphery of the City Forest near Schwanheim, Holland remarks: »Those trees have survived for many epochs, but the last few years have really taken a toll.«

Frankfurt City Forest is by no means the only forest that is currently suffering, as is evident in the Hessian report on forest conditions [*Waldschutzbericht*] for 2019. The average crown transparency of trees in Hesse's forests recorded in the report was 27 per cent, the highest rate recorded since Hesse began tracking this metric in 1984. 2.3 per cent of trees in Hesse died in 2019. While this might not seem like much, it is sevenfold the mortality rate for the previous year. In fact, since 1984, the rate had never exceeded one per cent before. Half of all the trees that died are Norway spruce trees. Well, they were Norway spruce trees. Spruce are particularly susceptible to bark beetles, although pines and beech trees are also afflicted by other pests.

Extremely hot, dry years

In addition to the changes made to woodland habitats by commercial forestry, the main factor

Frankfurt City Forest is suffering: dead and diseased trees testify to heat stress and drought.



About Wolfgang Brüggemann

Prof. Dr. Wolfgang Brüggemann, born in 1956, earned degrees in biology and chemistry and conducted postdoctoral research in Marburg and in Groningen in the Netherlands. He worked as a research assistant at the Institute for Environmental Plant Physiology in Düsseldorf and gained his habilitation (*venia legendi*) in botany in 1995 for his research on the development of chilling tolerance in the photosynthetic apparatus of the genus *Lycopersicon* (tomatoes). In 1997, he was called to a professorship in the Faculty of Biological Sciences at Goethe University. The project presented here is a cooperation project within the Senckenberg Biodiversity and Climate Research Centre.

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driving these problems is climate change. For one thing, winters have become milder. The population of harmful insects spikes after mild winters because more of them survive. In addition, climate change makes summers hotter and drier. The trees suffer directly from the resultant water stress, but they also became less resistant to insects.

2019 was the second-hottest year in Germany since the German Meteorological Service began tracking temperatures in 1881. It tied with 2014, while 2018 was the hottest year on record. There can always be a hot year every now and then, but in this case two extremely hot years came back-to-back. In addition to the exceptional heat – and the storms, which have also wrought extensive damage in the forests in recent years, as well – both years, and now also 2020, were drier than average.

Crown transparency is up for all species across all of Germany in comparison to last year. Over the next few decades, the composition of many forests throughout Germany will change.

The trouble with restructuring forests

Forests are an emotional topic for Germans. Much of Germany is forested – a third of the total area – and everyone has their own relationship to the greenery. People's individual interests vary greatly, too: some people want to hike or bike, while others want to harvest wood. Some want to protect animals, while others want to hunt. Each interest group has its own ideal forest, and the proposals span a gamut running from entirely *laissez-faire* approaches (»Just leave the forest alone; it will regulate itself«) to demands for cultivated plantations of neat rows of trees standing to attention. The tensions inherent between these varied viewpoints are now being further exacerbated by climate change and the urgent need to find and deliver solutions that it creates.

Brüggemann and Holland are on a mission to find a lasting compromise everyone – including the animals – can live with. They do not believe that there is time to wait for the forest to adapt to developments of its own accord. Nor do they believe that monocultures can work – they favour biodiversity instead.

Could the future forest be like a Spanish forest?

Brüggemann's approach to forecasting what might be able to grow in the future requires forecasting future conditions. Another trip into the future, if only an imaginary one. »In the immediate future«, he says, »we have to expect a climate like that of Freiburg, a little warmer and a little drier.« At some point, it will be even warmer and drier again and more like the current climate of Montpellier in southern France. »And finally, by 2100, we might have a climate like they have now in Barcelona, if the climate keeps changing as it has been changing up to now.« Travel, says Brüggemann, makes it possible to look forward in time, »as if we were driving into the future.«

And what trees do you see as you drive further into the future? What could supplant the European oak trees in Frankfurt City Forest? »The further we go towards the southwest,« says Brüggemann, »the more the forest changes.« In the Breisgau region around Freiburg, one already finds many sessile oaks instead of the local pedunculate oak. As you go further up the scale of drought-resistant oaks, you find downy oaks and evergreen holly oaks growing in southern France. In Spain, in areas at lower elevations, practically all the oaks found are holly oaks.

»Those that survive here can survive anywhere«

Does this mean that the holly oak will save the German forest? Or at least Frankfurt City Forest? For the time being, this is still just a thought game. As scientists, Brüggemann and Holland know that they must show that their ideas are feasible. Frankfurt offers a perfect opportunity to demonstrate this, because the City Forest is already experiencing extreme conditions today: it is dry, it is hot, and every thinning crown makes it hotter. The soil is almost entirely made of sand deposited here when the river Main was still close by. This sandy soil does not retain water. Normally, the trees can tap into the groundwater, but the water table has fallen so much that their roots are no longer deep enough. Other forests, which currently still have a sufficient water supply, will be affected by climate change in the future. Frankfurt City Forest, on the other hand, is already a prime example of how such changes can devastate a forest. This also means, as Brüggemann says, that »Those that survive here can survive anywhere.«

This is why the two plant ecophysiologicalists have their own fenced-in corner of the forest here. They are experimenting to see whether Hungarian, downy, or holly oaks can survive and thrive in this region. Their project, named SHOP – for »South Hesse Oak Project« – began in 2011. Brüggemann's research team began by planting small groups of several varieties of oak among the native flora. And not just in Frankfurt City Forest: as part of SHOP – and the subsequent expansion of the project with partners in Italy and Greece in 2017 in a cooperative project known as »Future Oaks IKYDA« – researchers have planted over 10,000 oaks, not only in southern Hesse but also as control groups in the species' native regions in Greece and Italy.

The forest has to like the trees

In front of one of these groups of trees in the City Forest, a white sign bears the text *Q. ilex* – i. e. holly oak. Vera Holland is standing behind it. She explains: »In order to study which varieties of oak thrive here, we take a number of physiological measurements in addition to recording the height and diameter of the tree.« They also record which trees survive. »The pedunculate oak, which is native here, grows very well, but then a lot of them die off«, Holland says. »The Mediterranean oak varieties that we have planted here have better survival rates, and the downy oak grows at least as quickly as pedunculate oak.«

A second important question is whether the forest habitat can thrive along with the trees. After all, no one wants a repeat of what happened with the black cherry, which is native to



About Vera Holland

Dr. Vera Holland, born in 1984, studied biology at Goethe University. She completed a dissertation on photosynthesis in oak hybrids in 2009 for which she was awarded the P&G Sustainability Award. Under Wolfgang Brüggemann's supervision, she completed a doctoral dissertation in 2015 about the effects of climate change on the ageing of European oak varieties.

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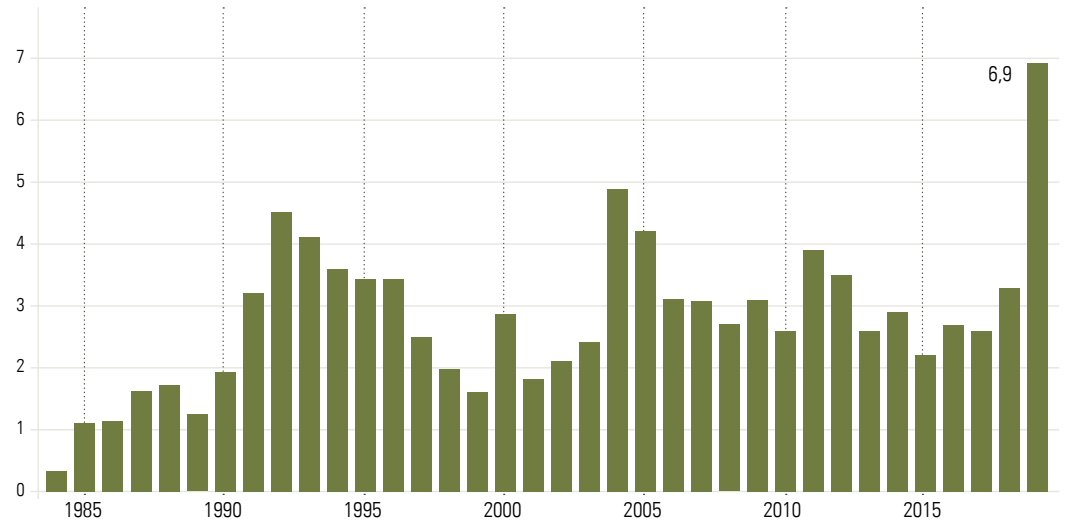
North America. It grows into large, attractive trees there, but when it was introduced into Europe, it turned out that the same species here grew more as a shrub and spread so quickly that the bushes often choked young native trees and robbed them of any light.

Why oaks, anyway? This preference goes back to the days when Brüggemann's institute was still in the Siesmayerstraße street in Frankfurt's Westend district. When research interns needed to measure photosynthesis in the winter, as occurred rather frequently, Brüggemann used to send them to a tree in the Botanical Gardens next door, an evergreen holly oak that was approximately six metres tall. The tree was so eminently suitable for this purpose that Brüggemann eventually planted a few holly oaks in the Institute's own garden in 2007.

Today those trees are living testimony against all who have rejected Brüggemann's suggestions and claimed that Mediterranean oaks cannot survive German winters. When the Institute moved to the new Riedberg Campus in

Percentage of extreme damage (including dead trees), tree species of all age classes

Stressed trees in Hesse
 The fact that more trees (as a percentage) in all age classes in Hesse were in extremely poor condition or died in 2019 than in every other year since 1984 is primarily due to the spruce trees. This species was extremely negatively affected by the droughts in 2018 and 2019, and the heat benefited bark beetles and other insect pests.



Source: Waldzustandsbericht [Forest status report] 2019, Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection

2012, the researchers even dug up the holly oaks and relocated them to the new experimental garden there. They survived the move, too, and today Brüggemann’s holly oaks are six metres tall and in the rudest of health.

downy oaks, along with some holly oaks, and leave the rest up to the natural succession of native species», Wolfgang Brüggemann answers. ●

Oaks harbour 400 types of insects

On a more serious note, oaks provide a valuable habitat for numerous species of fungi, lichens, and beetles – over 400 types of insects live on and in these trees! Brüggemann even counted those found just in the SHOP oaks: over 70 species of butterflies were spotted, and he estimates that they harbour at least 200 species of beetles. The majority of insects native to Germany that depend on oak habitats can also live in or around the Mediterranean oaks. Some of them could move to other trees if there were no more oaks, but many of them would be stuck. The great capricorn beetle, for example, one of Central Europe’s largest species of beetle at five centimetres long, is already endangered but still found in Frankfurt City Forest.

So what does Brüggemann and Holland’s research mean for Frankfurt City Forest? Can it be saved? And, if so, how should it be reforested so that it is likely to survive and maybe even thrive in the coming years, which are also likely to be warmer and drier? Its survival is important, for the forest captures the CO₂ the city produces and creates a cooling effect when the trees move water from the ground to the air. Brüggemann is somewhat reticent about giving policy advice, for he sees that as the role of politicians and forest managers. But what would he plant if he owned a bit of forest in this region himself? »As areas became free, I would plant primarily



The author

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IN A NUTSHELL

- Drought, heat stress, and the sandy soil have all contributed to the troubled state of trees in Frankfurt City Forest.
- This makes the City Forest an ideal location to experiment with climate-resilient trees that can cope with these conditions.
- In 2011, the South Hesse Oak Project (SHOP) planted oak varieties that thrive in southern Europe.
- The result: The southern European oak varieties have had higher survival rates than the native European oaks.