TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

Newsletter 1/2020

CONTENTS

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Spruce have been especially hard hit by the dry conditions. Drones are among the tools used by TERENO scientists – here Jülich researcher Carsten Montzka – to study drought damage and its consequences.

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Forests in distress

Germany's forests are not doing well. Drought, heat, storms, forest fires and pest infestations have taken their toll, with some tree species expected to disappear from Germany altogether. TERENO researchers are tracking the transition in Germany's forests and investigating its impact on the carbon cycle, water cycle and weather.

HELMHOLTZ ASSOCIATION

ICOS CERTIFIES TERENO SITES

The European carbon observation network ICOS awarded its “Class 1 Station” certification to two TERENO sites in 2019. The certification confirms that TERENO’s Selhausen and Hohes Holz sites continuously fulfill specific standards for measuring greenhouse gases.

Standardized measuring at TERENO sites Selhausen (l.) and Hohes Holz

Certifications such as the ICOS “Class 1 Station” involve extensive processes and quality testing. The goal is to standardize data collection and make it much easier for scientists to use data from different stations. In addition to the Selhausen and Hohes Holz sites – now with Class 1 Station certification – the ICOS network includes five additional TERENO sites, some of which have already initiated the certification process. TERENO sites are designed to help researchers recognize climate-related trends and the corresponding reactions on the part different ecosystems, and to provide data for climate assessments and forecasts.

Selhausen site

The Selhausen site in TERENO’s Eifel/Lower Rhine Valley observatory is comprised of a roughly 10 hectare field in lower Rhineland’s Börde landscape, primarily farmland. “The cultivation of sugar beets in the first year and winter grains in the second and third years of cultivation is typical of this area, which is why observations made at the Selhausen site can be considered representative of the regional agriculture,” says Marius Schmidt from Forschungszentrum Jülich. Installed at the site are two 3-meter high measurement towers which Jülich researchers use to continuously measure the exchange of greenhouse gases such as CO_2 and water vapor between soil, plants and atmosphere. Data is also collected on climate variables such as temperature, soil moisture and plant growth, as well as extreme weather events such as thunderstorms, flooding and drought periods.

Hohes Holz site

The Hohes Holz forest climate observatory is situated in a mixed beech forest of some 1,500 hectares which forms part of TERENO’s Harz/Central German Lowland observatory. The measurement area itself is roughly one hectare and includes a 50-meter measurement tower, which researchers use to investigate the exchange of greenhouse gases between plants and atmosphere. “Data from here is compared with results from neighboring sites – one pasture and one agricultural field – along with data from other sites around Europe,” explains Dr. Corinna Rebmann from the Helmholtz Center for Environmental Research – UFZ. To better understand the role of forests in climate change, UFZ researchers investigate, for example, how trace gas fluxes above a mixed beech forest with traditional forestry management at site such as Hohes Holz differ from fluxes above a mixed beech forest in its natural state.

ICOS

ICOS (Integrated Carbon Observation System) is a European research network that delivers coordinated, European-wide measurements of the carbon cycle, greenhouse gas emissions, as well as atmospheric concentrations of the major greenhouse gases. ICOS network sites are classified as Class 1 or Class 2 Stations depending on the site’s degree of standardization and the scope of its measurement program. Stations with lower degrees of standardization are labeled as “Associated Sites”.

EDITORIAL

Forests in transition

Forests are under stress today. According to the German Forest Condition Survey 2019, four out of five trees show signs of damage. But it would be incorrect to say that forests are dying. Instead, certain tree species are suffering – and for these trees, climate change will make it increasingly difficult to survive at our latitude. Which species will dominate our future forests remains uncertain, and it is not yet clear whether the dry conditions of the last few years are in fact the “new normal”. Here again we are reminded of the importance of a permanent infrastructure for environmental research. The cover story of this issue shares some insight into how we – with the help of TERENO observatories and in cooperation with national and international networks such as MOSES and ICOS – are monitoring and studying these changes to our forests. The data we are gathering provides the basis for models, and we hope to use these models to generate forecasts so that we can take effective action early. Among the other topics in this issue: why plants and soils might be releasing more water than previously thought, how the simulation of the future water cycle is being improved, and what might help wild bees.

I would also like to take this opportunity to welcome our three new Scientific Steering Committee members. It is a pleasure to have three women scientists joining the committee: Theresa Blume, Susanne Liebner and Nadine Rühr.

I hope you enjoy this issue of the TERENO newsletter!
Sincerely, **Harry Vereecken**

TERENO Coordinator

▶ ICOS
▶ Measurement data from May 2019, updated daily and available via the ICOS data portal
or via the
▶ TERENO data portal

WHY FORESTS HAVE A CLIMATE PROBLEM

Interview with Prof. Alexander Knohl, member of the TERENO Advisory Board

The geoecologist Alexander Knohl is Professor for Bioclimatology in the Faculty of Forest Sciences and Forest Ecology at Georg-August University of Goettingen. Since 2019, he is also a member of the TERENO Advisory Board. Knohl's research interests include terrestrial biosphere-atmosphere interactions, with a focus on carbon and water cycles and the impacts of land-use and climate change on these cycles. We spoke with Professor Knohl about Germany's forests and the challenges they face today.

Professor Knohl, you run a measurement station in the Hainich National Park, an old mixed beech forest in Thuringia on the list of UNESCO World Heritage sites. How do things look there?

On sunny, south-facing slopes we're seeing a lot of dead beech trees. Beech are not faring as poorly as spruce, which are dying by the kilometer in the Harz, for example. But the beech has long been considered a species well-suited for the future, and we're now seeing quite clearly that it, too, is struggling. It is faring better or worse depending on the region; in some parts of the Hainich it's pretty bad.

What are the signs of stress?

At Hainich, there has been a measurement tower in operation for the last 20 years. The tower is part of the European network ICOS (Integrated Carbon Observation System). The beech forest's CO_2 uptake numbers had remained largely stable over this time until the extremely dry conditions began in 2018. CO_2 uptake downright collapsed in 2018 – down by about a third. And that's with our measurement tower located on a north-facing slope where the trees are showing less damage, at least outwardly. On several days in August and September, the forest around our measurement station absorbed no CO_2 at all and even gave some off. I have never seen anything like that in our data. We did see a decrease in 2003 as a result of dry conditions, but the forest was able to recover quite quickly back then, unlike today.

What is different today?

In the last several years we have had an unusually high number of extreme climate events. In winter 2018, "Friederike" – one of the most severe storms in recent memory – caused tremendous damage in northern Germany and weakened a great number of trees. This was followed by an extremely dry summer 2018. Then came 2019, another very warm and dry year, and finally winter 2019/2020, the warmest winter on record in Europe.

How are beech trees responding to this?

The dry conditions have resulted in decreased soil water content, so the trees can't get the water they need. They don't die right away. They start by closing the stomata on their leaves in order to conserve water. But that also means the leaves absorb less CO_2, photosynthesis levels drop, and tree growth slows. If the dry conditions persist, the leaves turn color earlier in the year. And because the beech constrict their stomata, transpiration rates decrease, i.e. the leaves give off less water. So now if the tree gets a lot of sun – when summer weather is hot and dry – the surface of its leaves heats up. The trees emit this heat into the atmosphere, which can create a positive feedback loop on the regional level. Colleagues at ETH Zurich, for example, have shown that these positive feedback loops can magnify the effects of droughts. Still, more research is needed to better understand the details. And for that we need long-term infrastructures such as ICOS and TERENO. Some of the TERENO sites are already part of the ICOS network, of course.

How do these kinds of infrastructures help?

They are key to understanding the processes involved. Thanks to the data they provide, we can monitor changes over longer periods of time and identify any positive feedback loops between soils, plants and atmosphere, for example, or see what happens in spring and what impact it has on the following summer. For instance, we are currently using ICOS to collect different datasets on the highly unusual winter of 2019/2020. The TERENO sites are particularly important because they take the entire water cycle into account, for example. The modeling provided by the Helmholtz institutes involved in TERENO is also key. These make it possible to forecast future conditions and even develop warning systems, which could provide important input to both forest owners and farmers.

Should certain measures be adopted already today?

First, it's important to understand that the underlying problem is not the changes in our forests, but the change in the climate.

© Universität Göttingen

Prof. Alexander Knohl

The plight of forests today has made this all the more clear. We need to limit climate change as much as possible and stay within the target of 1.5 or 2 degrees Celsius. And that means drastically reducing carbon emissions. In terms of forests, we need to find species that can handle the climate of the future. The longstanding effort to increase the amount of mixed forest is a good approach.

Should we be prioritizing native or non-native trees species?

This is a hotly debated topic. It's a hard question to answer given the lack of past experience. It certainly makes no sense to prescribe one single solution. Decisions should be made on a site-by-site basis, since every location is different. You also have different requirements and expectations among the many different forest owners, and in society. We need to understand that forests today are more than just suppliers of timber. Forests provide us with recreational areas, they help protect our drinking water, preserve biodiversity and protect our climate at the same time. These important functions need to be maintained adequately at the local level, even as conditions become more and more challenging.

TROUBLED FORESTS

For the third year in a row, weather in Germany has been too hot and dry – and the impact on forests has been huge. Adding insult to injury, mild winters have allowed pests like the bark beetle to survive. TERENO researchers are monitoring how spruce, beech and other trees species are handling extreme drought stress, record heatwaves and pest infestations. And they are investigating the impact on atmospheric CO_2 levels, evapotranspiration, and weather conditions.

When Nicolas Brüggemann looks over the northern Eifel from one of his research sites in Kleinhau, he worries: "In the past we couldn't see more than 100 meters because of all the trees blocking our view; today, when visibility is good, I can see the Siebengebirge hills outside Bonn, and that's a good 60 kilometers away." For Brüggemann, Professor of Terrestrial Biogeochemistry at the University of Bonn and head of the Plant-Soil-Atmosphere Exchange Processes research group at Forschungszentrum Jülich, there is no doubt about it: the forests of the northern Eifel ("Nordeifel") have been changing for years now, becoming more and more sparse. "This is mainly due to a combination of damaging factors that we haven't seen before, ranging from drought to hot temperatures to forest fires, storms and pest infestations," explains Brüggemann.

In the Nordeifel, spruce trees have been hit hardest by the combination of prolonged drought and bark beetle. Particularly alarming is the fact that mild winters are allowing the bark beetle to move to the gradually higher elevations of Germany's uplands. At TERENO's Wüstebach site in the Eifel National Park, at around 600 meters, the damage has been minimal thus far. But farther down in the Eifel foothills ("Voreifel") it's a different picture, dominated by dead spruce with bare brown branches and pale trunks. But spruce trees aren't the only ones struggling: "By August 2020, the beeches in Eifel National Park were showing colors you normally see in fall," says Brüggemann. "And oaks are suffering too, either because of insects or fungi."

For Brüggemann, the current situation is significantly worse than the forest dieback seen in the 1980s: "The damage back then was certainly large-scale, but it was brought under control with measures such as emission controls for power plants and vehicles." Brüggemann also feels that the term "forest dieback" seen so often in today's news is actually misleading: "It's not the forest as an ecosystem that is dying; instead, certain tree species are disappearing and gradually being replaced by others."

Conifers feeling the drought stress

2018, 2019 and 2020 – three dry years in a row have taken their toll. Experts estimate that drought, forest fires, severe storms and bark beetle infestations have ravaged more than 160 million cubic meters of wood across an area of about 245,000 hectares in these last three years alone. And coniferous trees such as pine, spruce and fir are particularly stressed.

In the Eifel, spruce trees comprise roughly two-thirds of the tree population although they are not native to the region. As was common in Germany following World War II, spruce trees were planted in large numbers despite the fact that they normally grow only in Central Europe's higher altitudes and in the boreal coniferous zone. Their fast-growing, straight trunks were in great demand – a quick way to meet Germany's growing needs for wood for both fuel and construction material. Back then, nobody was thinking about climate change. But with its shallow roots, the spruce is very vulnerable when conditions turn dry: "Droughts tend to be rare at higher altitudes, but here in our temperate latitudes, we've experienced just that over the last three years – in a very concentrated form," says Brüggemann. In the northern Eifel, spring 2020 started off again with extremely dry weather, which gave the trees no time at all to recover. And weakened trees are even more attractive and vulnerable to pests like the bark beetle.

Beeches suffering too

In the northern Eifel, the European beech is also in trouble. Beech are best suited to a temperate oceanic climate with relatively high amounts of precipitation and only moderate temperature fluctuation. In the 2018

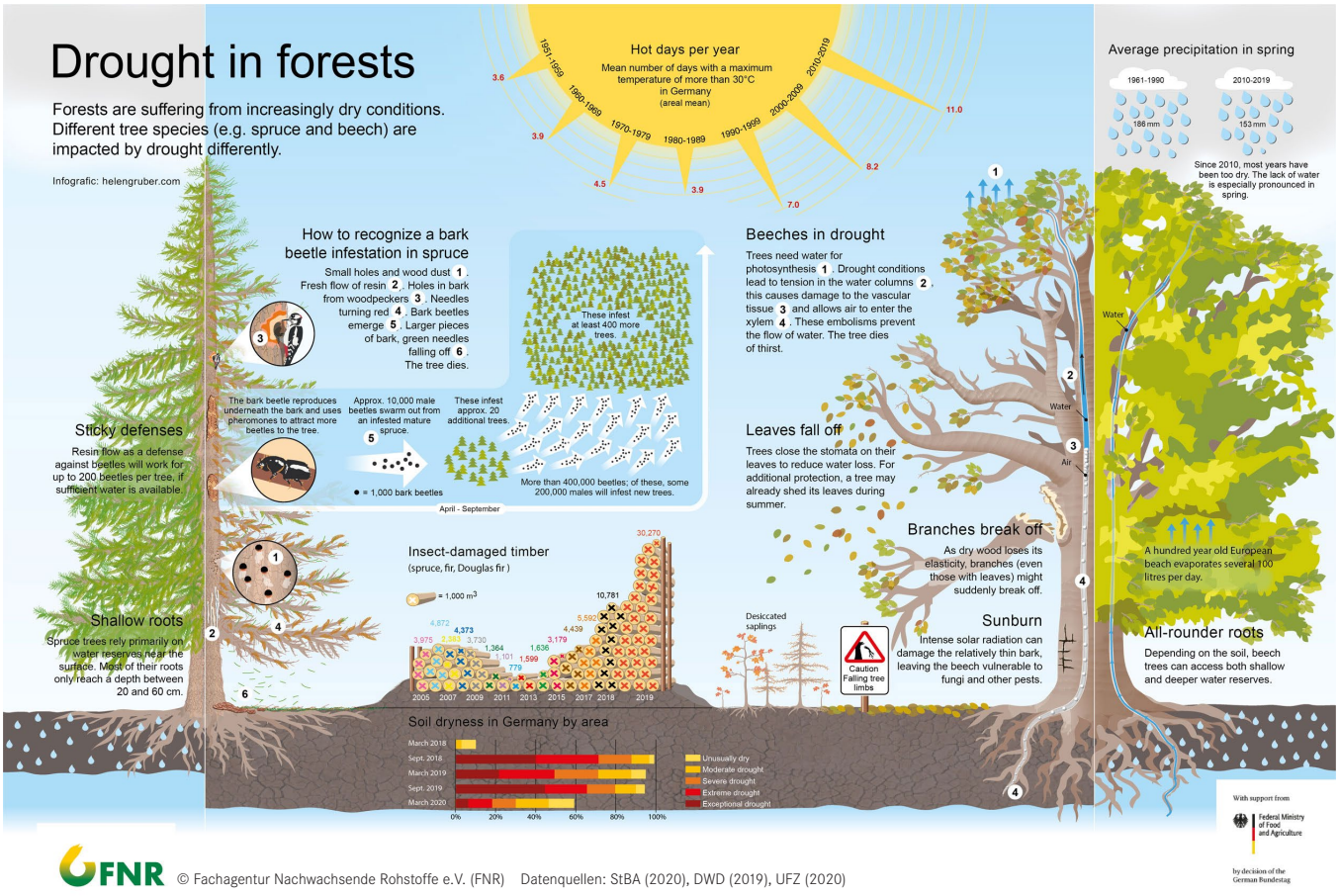
drought year, Brüggemann had already observed beeches on the Forschungszentrum Jülich campus that had suffered sunburn and then died the following year. “That’s something we can expect now in the Eifel, too,” says Brüggemann with concern. It has been – and continues to be – too warm and way too dry. Many foresters no longer know which native tree species they should even plant, and are deciding more and more in favor of North American species such as the red oak, since these are less vulnerable to pests, heat and drought.

Alexander Graf gathers data on the CO_2 exchange between soil and atmosphere.

A conversion effort, and lessons learned

The Wüstebach site in TERENO’s Eifel/Lower Rhine Valley observatory provides an exceptionally good backdrop for studying and forecasting the longer-term impact of the ongoing drought. Not only is the area equipped with a diverse range of measurement instruments, it is also the site of an ongoing forest conversion experiment initiated by the national park service. Back in 2013, park officials in the northern Eifel began removing all spruce trees from an 11-hectare area within Wüstebach site to accelerate efforts to restore natural deciduous forest within the park. This dealt an initial blow to the CO_2 balance, since forest trees usually absorb CO_2 from the atmosphere. Without trees, the area became a carbon source rather than a carbon sink, with the soil continuing to release CO_2 as it processes the humus from decaying plant and animal matter.

TERENO researchers like Brüggemann and his colleague Dr. Alexander Graf from the Institute of Bio- and Geosciences (IBG-3) have been monitoring the forest conversion process from the beginning. “The impact of this rather drastic measure on the soil, water quality, exchange processes and the composition of flora and fauna offers an opportunity to better understand the forest regeneration process,” explains Graf, who is measuring factors such as CO_2, water vapor and energy exchange between the land surface and atmosphere. The aim of the researchers is to extrapolate the data to better understand how such drastic deforestation, on a larger scale, impacts a forest’s ability to absorb carbon dioxide. In addition to monitoring the impacts of this forest conversion, researchers can also better understand the impact of damage due to drought and bark beetles. And these impacts are complex to say the least: “We are seeing an impact on evaporation, on climate and weather conditions,” says Brüggemann.



The water vapor problem

If less carbon dioxide is absorbed, much less water vapor is released by the trees. This has its advantages and disadvantages. With all the spruce removed, the air above the forest floor warms quicker. There is no buffer layer, so on a hot summer day the sun beats directly down on the ground. "Using drones and thermal cameras, we've measured ground temperatures up to over 60°C," says Brüggemann. As a result, a tremendous amount of warm air rises into the atmosphere, which amplifies the heatwave. On the other hand, the lack of trees means there are no big thirsty water "consumers" extracting water out of the soil. "This can be a plus for water supplies and groundwater, but – especially in steeper terrain – can also result in hillside erosion. When rainfall is heavy, the surface runoff takes the soil with it, even an entire hillside," explains Brüggemann.

Seven years later, a new forest is gradually taking root on the cleared area. But measurements taken by Graf, Brüggemann and their TERENO research team reveal that it is still far from the CO_2 uptake capacity it used to have. Nevertheless, the team was amazed by how quickly the forest recovered in the first few years – that is, until the droughts came. Analyses show that e.g. photosynthesis levels decreased significantly in 2018 and continue to stagnate at subpar levels. "The new vegetation first needs to deal with the fact that conditions are drier than usual," explains Graf. The researchers found that CO_2 uptake in the adjacent spruce forest was also significantly below average over the last three years of heat and drought.

Forests most resilient in 2018

A recent study initiated by the European research infrastructure ICOS (Integrated Carbon Observation System) investigated the effects of Europe's 2018 drought. Alexander Graf, who played a significant role in the study, analyzed measurement data from 56 different sites. 46 sites in the northern half of Europe experienced drought and above-average temperatures, with below average rainfall and higher potential evapotranspiration. "For all ecosystem types affected by the drought – whether forest, cropland or grassland – CO_2 uptake was down in 2018 as compared to previous years," sums up Graf.

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Jülich researchers Jannis Jakobi (l.) and Heye Bogena with the MOSES cosmic-ray rover

MOSES test campaigns in Kleinhau and Hohes Holz

The Helmholtz project MOSES (Modular Observation Solutions for Earth Systems) develops and tests flexible and mobile measurement modules to research the interaction of short-term extreme events and long-term trends. From May to October 2020, MOSES researchers conducted a measurement campaign in Kleinhau in the Eifel region to investigate how the dry conditions of the last several years have impacted forest and soils. The 328 hectare private forest, which is actively managed, consisted primarily of spruce trees. Under severe stress due to drought and bark beetle infestation, over 90% of the spruce had been cut down by summer 2020. The reforestation effort, overseen by forest administrator Burkhard Priese, relies mainly on trees considered less vulnerable than the spruce: the native chestnut and the North American red oak.

"For us it was a good opportunity to investigate the impacts of deforestation and subsequent reforestation," says Jülich expert Prof. Nicolas Brüggemann. The researchers used a number of mobile and stationary measurement instruments: a mobile neutron detector (cosmic-ray rover) to measure soil moisture across the entire area, a mobile land ecosystem–atmosphere flux module to measure CO_2 and water vapor fluxes between soil and atmosphere, as well as drones fitted with thermal and multispectral cameras. The data gathered provides a valuable addition to the extensive measurements taken at TERENO's Wüstebach site in the Eifel National Park, where a monoculture spruce forest was converted to a more native deciduous forest beginning in 2013.

Additional TERENO members were also involved in the MOSES campaign in Kleinhau: Forschungszentrum Jülich, the Karlsruhe Institute of Technology, and the Helmholtz Centre Munich – German Research Center for Environmental Health. Parallel to the MOSES campaign, fellow researchers from the Helmholtz Centre for Environmental Research – UFZ and the Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ) conducted measurements to determine the impact of drought conditions on forests at TERENO's Hohes Holz site near Magdeburg. Researchers plan to analyze the combined data from the Kleinhau and Hohes Holz sites by the end of 2020.

This could have drastic consequences, since scientists predict that extreme heat and drought will occur more frequently in the future. In response, forests in Europe would protect themselves by releasing less water and slowing down their growth, which also means decreased CO_2 uptake. “If these ecosystems absorb even less carbon dioxide from the atmosphere in such drought periods, we lose an ally in the fight against global warming,” explains Graf.

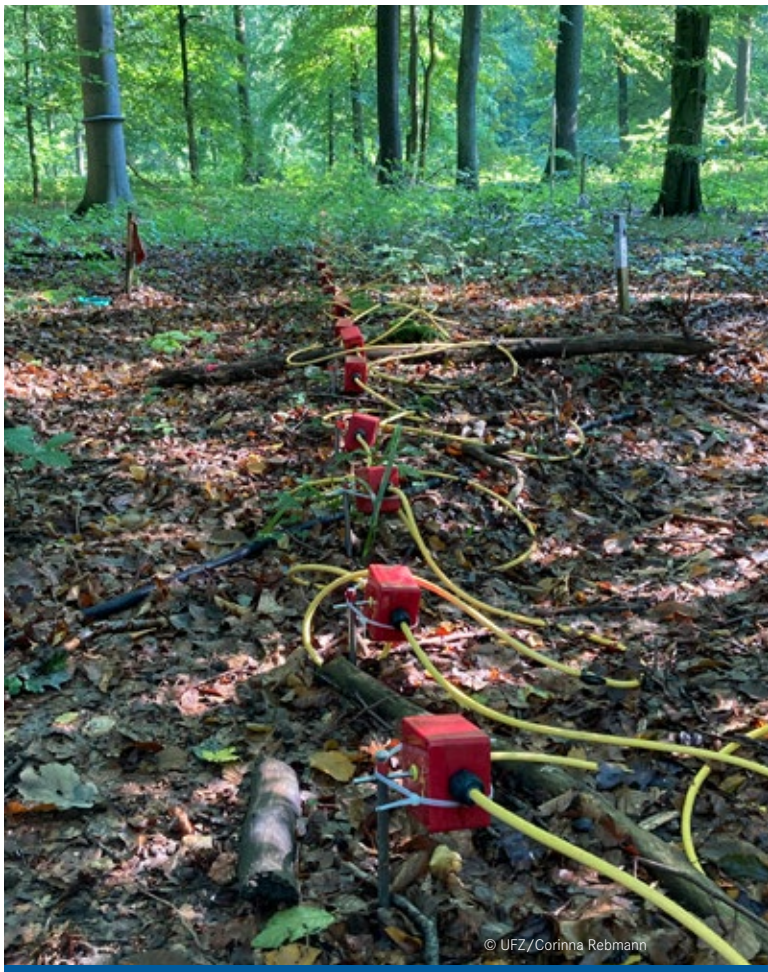
The study also revealed that forests could attenuate the effects of drought better than other ecosystems. On average, CO_2 uptake by terrestrial ecosystems decreased by 18% in 2018. For croplands, grasslands and peatlands, uptake decreased by significantly more – up to 40%.

But for forests, it was just 8%. “There are a number of reasons why we shouldn’t overplay a result like this, but it is a sign that forests can absorb the shock of a drought better than other ecosystems,” says Graf. So if the goal is to absorb a lot of carbon dioxide, having a lot of forest is a good thing.

“Hohes Holz” less affected

The “Hohes Holz” site in TERENO’s Harz/Central German Lowland observatory is among the measurement stations being used in the European ICOS study. A forested area with high-quality, nutrient-rich soil in the foothills of Germany’s Harz Mountains, “Hohes Holz” is home to primarily beech and oak trees. Precipitation is generally lower here compared to the Eifel region. “Our trees are already accustomed to less precipitation than the trees in the Eifel,” says Dr. Corinna Rebmann, from the Helmholtz Centre for Environmental Research (UFZ), Department of Computational Hydrosystems. Rebmann is responsible for coordinating the ecosystem sites within TERENO and ICOS.

As in other parts of Germany, the Hohes Holz site experienced relatively high precipitation levels in winter 2017/18. “The vegetation benefitted from this, especially in spring 2018. Still, the gross primary production – the production of biomass by plants through CO_2 fixation – during the drought year 2018 was significantly lower in Hohes Holz as well,” says Rebmann. A very dry winter 2018/19 then induced an even more marked decline in gross primary production in 2019. “This is reflected not only in the data on water (evapotranspiration) and carbon fluxes from the eddy covariance method, but also confirmed by tree growth measurements using dendrometers,” says Rebmann. “In September 2019, the growth rate for oak and beech trees was significantly lower.” The 2019 leaf harvest also revealed that beech leaves did not fully develop during that year. Incredibly, this seems to have improved in 2020 despite the dry conditions. “I don’t yet have an explanation for that,” says Rebmann.



© UFZ/Corinna Rebmann

At the Hohes Holz site, 2D geoelectrical measurements continuously monitor changes in subsurface water content to a depth of approx. 6 meters.

In the Eifel near Kleinhau. Some of the damaged or dead spruce have already been cleared.

© FZ Jülich/Carsten Montzka

Rebmann and her colleagues have been collecting data at the Hohes Holz site since 2014. Even though the productivity of the beech and oak trees has declined measurably, they do not yet exhibit the kind of outward damage that would be recognizable to a lay person. Nevertheless, the researchers fear that another dry year could really degrade especially the beech trees, and that damage would then become visible. Either way, the region's foresters are plenty concerned already, and thinking a lot about forest conversion. More and more, researchers are wondering whether the past three drought years might be a better indication of what's to come than the decades before. "We need to consider whether 2018, 2019 and 2020 represent the 'new normal'," says Rebmann. According to Rebmann, this makes long time series, such as those tracked by TERENO and ICOS, all the more valuable – not only because they provide well-founded documentation of the changes in forests, but also to improve identification and understanding of processes and causes.

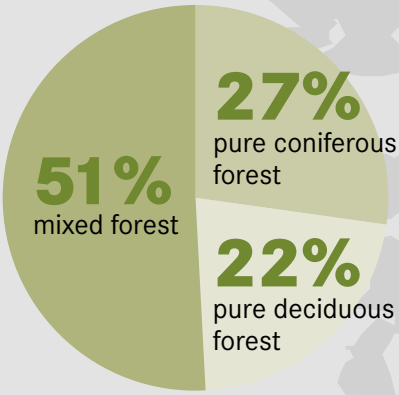
The beech as environmental archive

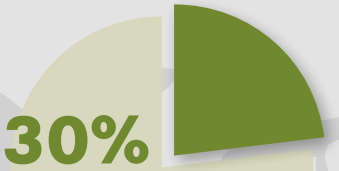
One such time series – spanning a good 1,000 years – was analyzed by a research team from the University of Greifswald and the German Research Center for Geosciences (GFZ) in Potsdam, along with other universities and research institutes, as part of a study focused on beech. The data is based on beech trees in Müritz National Park, some of which are up to 300 years old, as well as on old building timber from the last thousand years. "Because beech trees are particularly sensitive to periods of drought, the growth rings allow us to see how dry each year of the last Millennium was," explains Dr. Ingo Heinrich, one of the co-authors from the GFZ and coordinator of TERENO's Northeastern German Lowland observatory.

Tree growth rings provide a unique archive of past environmental conditions. If climate conditions favor tree growth, the rings are wide; if conditions are less favorable, the tree grows less and the rings are narrow. "The results allow us to take this high-resolution growth data from our TERENO tree monitoring over the last few years and place it in a much larger context of data from the last 1,000 years or so. This gives us a way to compare growth patterns and allows us to better contextualize what we've seen these last few years," says Heinrich.

THE NUMBERS ON GERMANY'S FORESTS

Forest-type distribution



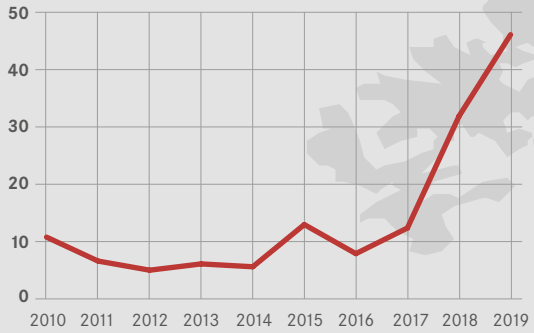


30%
of land coverage in Germany is forest
– that's about **10.7 million hectares**.

Source: Federal Statistical Office, Federal Ministry of Food and Agriculture

Logging damaged trees

in million cubic meters



For many years, roughly the same amount of timber was harvested from damaged trees. In 2018 and 2019, the numbers rose markedly.

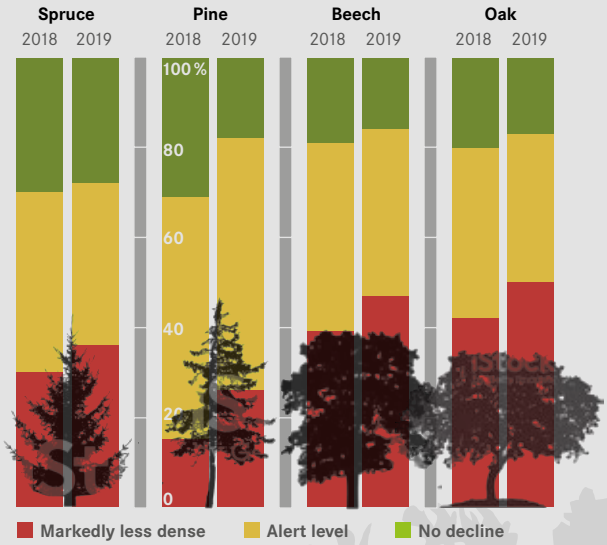
Source: Federal Statistical Office, 2020

62
million tonnes of carbon dioxide
are absorbed from the atmosphere by Germany's forests each year.

That represents about 8% of the 805 million tonnes of greenhouse gas emissions generated by Germany in 2019.

Source: Carbon Inventory 2017, German Environment Agency

Crown as indicator of tree health



Source: German Forest Condition Survey 2019

If a tree is under stress, it sheds leaves, fruit or even branches, and the tree crown becomes less dense. Germany has gathered tree crown data every year since 1984. For all tree species, tree crowns were worse off in 2019 compared to the year prior. On average, tree crown density has never been worse.

Medieval droughts

One of the study's more important findings is that the dry summer conditions experienced in 2018, for example, were nothing unusual back in the Middle Ages. "Apparently, beeches do survive these kinds of drought periods, but do so in part by establishing very low growth levels," explains Heinrich.

With the help of their monitoring data, the research team found that growth rates among beeches in 2018, despite the extreme conditions, were 65% higher than the long-term average. The Scots pine, on the other hand, reduced its growth rate in 2018 by 60%, while the oak exhibited no change compared to previous years. "The beech probably benefitted from the favorable conditions in April and May, early in the growth phase," says Heinrich. After the humid winter 2017/18, the soil was wet; at the same time, temperatures rose abruptly in late May. "This combination of factors seems to have been good for growth, particularly for the beech," says Heinrich. But the situation in 2019 was much different. Beeches hardly grew at all, and formed only a very small growth ring. "Winter precipitation levels were low so the soil was too dry and, presumably, the trees didn't have enough water. This suggests that the lack of reserves in spring 2019 resulted in retarded growth, because the trees, after their winter rest, first needed to form new photosynthetic products, with which the wood cells of the 2019 growth ring were then produced," explains Heinrich.

It remains to be seen what 2020 will look like. The research area did receive some occasional rain in June and July, at least. This benefitted the trees more than the local water balance; it was not enough to restore groundwater levels, for example. For lakes in the area fed naturally by groundwater and precipitation, water levels were correspondingly low.

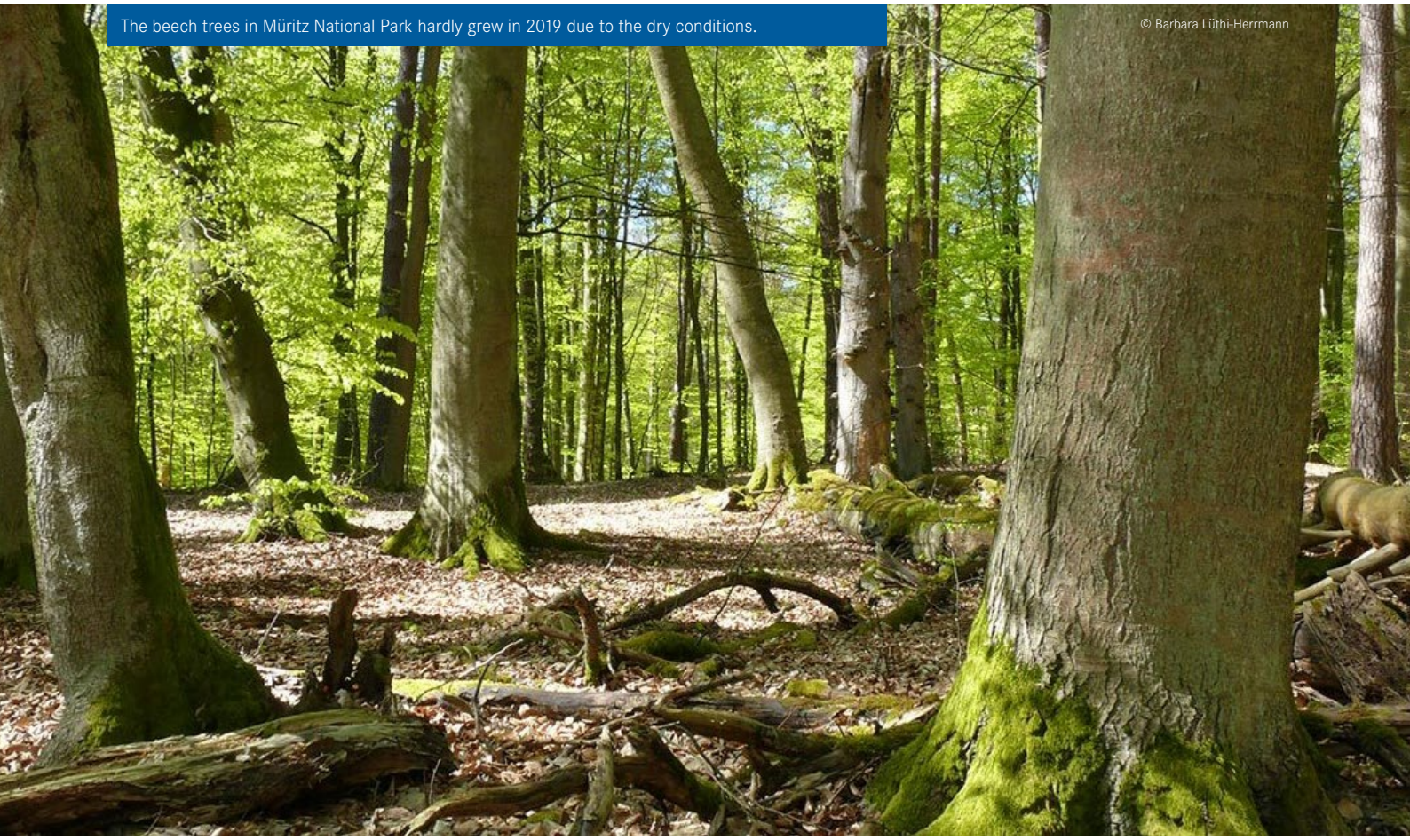
Similar to the Hohes Holz site, the mixed forest in Müritz National Park farther north is doing well compared to Germany's spruce forests. So far, the research area has been spared any major pest infestations. "But we're pushing the limits on what these trees can withstand. If more droughts follow, even the natural forests in the National Parks will have problems," warns Heinrich.

Alexander Graf, et al. (2020). *Altered energy partitioning across terrestrial ecosystems in the European drought year 2018. Philosophical Transactions of the Royal Society B, Band 375, No. 1810.*

▶ DOI: 10.1098/rstb.2019.0524

Tobias Scharnweber et al. (2019). *Removing the no-analogue bias in modern accelerated tree growth leads to stronger medieval drought. Scientific Reports, 9, Article number 2509.*

▶ DOI: 10.1038/s41598-019-39040-5



The beech trees in Müritz National Park hardly grew in 2019 due to the dry conditions.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Forest expert Nadine Rühr studies how trees respond to stress.

Heat and drought slow CO_2 uptake

Dr. Nadine Rühr is among those worried about the future of forests in Germany. Rühr heads the Plant Ecophysiology Lab at the Karlsruhe Institute of Technology and, since 2020, is a new member of TERENO's Scientific Steering Committee. "We know that climate change and the resulting extreme weather will change our forests, but it is difficult to quantify just how many trees will die because of it – in part because of a lack of coordinated research thus far," says Rühr. According to Rühr, spatially-diffuse tree mortality caused by factors such as drought or heatwaves, is much more difficult to quantify than tree death caused by heavy winds or bark beetle infestation. To better understand, quantify and predict tree mortality trends, Rühr joined with colleagues to found the International Tree Mortality Network, which brings researchers and forest experts together from around the world to develop a globally comprehensive picture of tree mortality in global change.

Rühr has also investigated whether the increase in atmospheric CO_2 concentrations might help trees better withstand hot drought extremes in the future. Her research on Aleppo pine trees, which are intensively grown in Mediterranean latitudes and are well-adapted to dry conditions, found that Aleppo seedlings hardly benefit from higher CO_2 concentrations, despite the fact that CO_2 is the limiting factor of photosynthesis. "You might think that higher CO_2 levels would help the trees to grow better," says Rühr. But her results tell a different story. Her research group investigated how doubling current levels of CO_2 concentration under hot and dry conditions would impact carbon metabolism and water-use efficiency in Aleppo pines. Their analyses show that increased CO_2 levels combined with heat stress resulted in decreased water loss and increased water-use efficiency in the trees – so a "plus" in terms of water budget.

But the team also found a strong decline in net carbon uptake resulting in loss of C. "If it's too hot and dry, the stomata on the needles remain largely closed to avoid further water loss through evaporation. But that also prevents CO_2 from entering the needles," explains Rühr. As a result, the metabolism can hardly take advantage of the CO_2 surplus. Hence, any positive impact of elevated CO_2 on tree stress responses was small, and disappeared almost entirely with progressing heat and drought. For Rühr it is clear: "The increase in atmospheric CO_2 cannot counterbalance the impacts of hot drought extremes in Aleppo pine and likely in other pine species as well."

And the longer-term impacts of sustained drought periods on trees remain uncertain. "You might think that a conifer like a pine would recover quickly once it finally rains again," explains Rühr. But that is not always the case. If the drought stress is too severe, the tree can suffer irreparable damage. A tree will react to water shortages by closing its stomata to prevent further water loss. In a pinch, a deciduous tree can respond by shedding its leaves to protect against dehydration. But conifers don't have much of an option. If the hot and dry conditions persist, they will continue to lose water even after closing their stomata, and eventually dry out. And if there is no more water coming up from the ground, the tree's water transport system, its hydraulic plumbing, can fail. "Air pockets start to form in the xylem, the vascular tissue that normally conducts water," explains Rühr. Researchers refer to this as xylem embolism. One experiment conducted by her working group could show for the first time that these air bubbles remained in Scots pine seedlings, even a month after watering is resumed. Upward transpiration is thus reduced, stomata remain only partly open, and photosynthesis levels are diminished as well. "The role such embolisms play in spatially diffuse tree mortality and a tree's ability to recover from drought is not yet clear," sums up Rühr, who hopes that access to significantly more data – including data from TERENO observatories – will help shed more light on the subject.

Bernhard Schuldt et al. (2020). *A first assessment of the impact of the extreme 2018 summer drought on Central European forests. Basic and Applied Ecology, Volume 45, pp. 86-103.*

▶ DOI: 10.1016/j.baae.2020.04.003

Benjamin Birami et al. (2020). *Hot drought reduces the effects of elevated CO_2 on tree water use efficiency and carbon metabolism. New Phytologist, Volume 226, Issue 6, pp. 1607-1621.*

▶ DOI: 10.1111/nph.16471

▶ International Tree Mortality Network

"DIVERSITY SPREADS THE RISK"

Interview with State Secretary Uwe Feiler on the state of Germany's forests

Uwe Feiler has served as Parliamentary State Secretary under Federal Minister of Food and Agriculture Julia Klöckner since 2019. Among his responsibilities: ensuring the exchange of information between the German government's executive and legislative branches. Feiler spoke with us about the Ministry of Agriculture's plans for forest conversion, the 800 million euros earmarked for forests following the 2019 National Forest Summit, and the fight against climate change.

State Secretary Uwe Feiler

State Secretary Feiler, in summer 2019 Minister Klöckner commented that everyone was talking about forest dieback in the 1980's, but today hardly anyone is talking about it, despite the fact that large parts of Germany's forests are in fact dying. How would you assess the state of Germany's forests today, one year later?
I think a lot of people understand the urgency of the situation. Our forests have been under permanent stress for three years now. Storms, drought and the bark beetle have caused tremendous amounts of damage. Germany's federal government and state authorities have made some 800 million euros available for converting forests into more climate-stable mixed forest. The economic stimulus package adds another 700 million euros for forests and increased wood usage. We are promoting forest conversion, and building public awareness about how important forests actually are for our health and well-being, for the economy and for the climate.

How have the funds you mentioned been used so far?
As a rule, the states are responsible for implementation. So they decide, within the scope of the overall defined objectives, how the funds are distributed among the different action areas. The 800 million forest aid package focuses on forest protection, combatting the bark beetle, as well as reforestation and forest conversion. The 700 million forest and wood stimulus package has three focus areas: 500 million for forest conservation and sustainable forest management, a 100 million investment program in forests and the wood industry ("Wald und Holz"), and another 100 million to promote climate-friendly construction with wood.

As of summer 2020, less than a quarter of the funds earmarked for 2020 had been paid out. Why is that, and how can this be accelerated?
The states alone are responsible for the distributing the funds from the 800 million aid package. They define the funding guidelines and requirements, and are responsible for the application and approval process. We expect them to establish these processes in such a way that forest owners can access the available funds as easily and unbureaucratically as possible. That is key to making sure the earmarked funds actually get to where they are needed around Germany. We have done our part in the federal government to make sure the agreed federal funds were made available quickly.

Are there plans for additional funding measures?
We have appointed a state and federal working group to advise us on how we might be able to "reward" forests and sustainable forestry practices for the fact that they reduce atmospheric CO_2 levels by some 127 million tons annually. Some are calling this a "Baumprämie" (tree bonus).

2020 also threatens to be a very dry year. Experts fear that climate change will cause more frequent droughts, and there are calls for adaptation measures for forests and forestry. Which measures does the ministry consider most promising?
Diversity spreads the risk. Mixed forests are best suited to adapt to climate change, and we are promoting this kind of forest conversion. We have taken a very clear position on this: when it comes to reforesting damaged forests, purely coniferous stands or mixed forests with less than 30% deciduous trees are generally not eligible for funding. We are also working together with the research community and supporting them. As an example, various tree species with genetic variations are being investigated at different locations with varying climatic conditions.

The federal government's Climate Action Programme 2030 plays a central role in Germany's fight against climate change. As part of the program, Germany wants to reduce its annual greenhouse gas emissions from agriculture from roughly 70 million to 58 million tonnes. Where and how can agriculture reduce emissions?
First off: the agricultural sector produces our food, and this results in unavoidable emissions. It is also true that hardly anyone suffers from climate change as much as our farmers. A year that is either too dry or too wet can mean heavy losses for their business. So agriculture is both agent and victim of climate change, but also offers solutions, since binding CO_2 can be accomplished through land use in a number of ways. We were the first ministry to present a 10-point plan to Germany's Climate Cabinet, and our plan addresses exactly that. Our goal is to promote humus accumulation in our arable soils, to preserve permanent grassland, to protect marshland and promote sustainable forestry. As mentioned earlier, forests and forestry in Germany bind over 127 million tonnes of CO_2 annually, which represents roughly 14% of Germany's annual CO_2 emissions.

11TH TERENO WORKSHOP – THE DROUGHT YEAR 2018

TERENO Workshop participants at the Research Center for Geosciences (GFZ) in Potsdam

More than 100 experts convened in Potsdam in September 2019 for the 11th TERENO workshop entitled "The Drought Year 2018 - Insights from the TERENO Observatories". Prepared by the Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ), the workshop focused on the impact of the unusually hot and dry weather in 2018. TERENO's yearly workshop is a chance for TERENO scientists to share their latest research and insights with each other as well as with collaborative partners throughout Germany and internationally.

Following the opening address by Prof. Reinhard Hüttl, Chairman of the Board and Scientific Executive Director, GFZ Potsdam, Dr. Florian Imbery from Germany's National Meteorological Service (DWD) provided an overview of 2018's extraordinary weather. Prof. Rüdiger Glaser from the University of Freiburg, an expert in historical climatology, presented a 500-year climate analysis up to 2018 using historical documents and data. While pointing out that devastating droughts have also occurred in the past – in 1540 and 1947, for example – he also noted differences in vulnerability and resilience of different societies over time.

Workshop presentations covered a broad spectrum – from a drought monitor developed by the Helmholtz Centre for Environmental Research – UFZ, to a detailed analysis of tree growth and tree water use in the TERENO NE forest observatory in 2018. These were followed by two mini workshops: one on the effects of 2018's extreme weather on the relationship between soil, plants and atmosphere, and the second on strengthening ties between TERENO and other initiatives such as the MOSES Earth observation system and the ESM Earth system modeling project.

The 11th TERENO Workshop was also an opportunity for the independent scientists on the TERENO advisory board to convene. The board praised what it considered to be highly successful TERENO research.

WÜSTEBACH MEASUREMENT CAMPAIGN

View from above: airship hovering over the site

In fall 2020, the "Cosmic Sense" research unit funded by the German Research Foundation (DFG) is conducting a multi-week measurement campaign at TERENO's Wüstebach site to measure soil moisture dynamics across the entire upper Wüstebach catchment area. In addition to the TERENO instruments available at the sites, the research team is using 15 stationary cosmic ray neutron (CRN) probes along with three mobile cosmic ray rovers and an airship equipped with a neutron detector. The CRN sensors allow the researchers to measure variations in neutron intensity at the Earth's surface, which can then provide a clearer picture of water distribution in the soils. By applying this method, the researchers hope to learn more about how precipitation, evaporation and water percolation through the soil affect both soil moisture and plant water storage in a catchment. The goal of the researchers, who also use drones and a gravimeter as part of the campaign, is to both improve their understanding of water cycle processes and optimize hydrological models. Taking part in the campaign are the University of Potsdam (project lead), TU Berlin and Heidelberg University, as well as four TERENO members: Forschungszentrum Jülich, Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ), Karlsruhe Institute of Technology and the Helmholtz Centre for Environmental Research.

▶ DFG research unit "Cosmic Sense"

FIRST INTERNATIONAL OZCAR-TERENO CONFERENCE: ADVANCING CRITICAL ZONE SCIENCE

Tentatively scheduled for October 2021* | Strasbourg

The French research network OZCAR (Observatoires de la Zone Critique : Application et Recherche) has joined forces with TERENO to co-organize a joint international conference on Critical Zone research every two years. The kick-off is tentatively scheduled for October 2021 in Strasbourg, France. Conference focus topics include exchange processes between soil, vegetation and atmosphere and their long-term observation, as well as the latest measurement, sensing and modelling methods. The conference will feature lectures, oral presentations and poster sessions in a variety of disciplines – from hydrology and soil science, to geophysics and geochemistry, to ecology and socio-ecology.

The joint German-French conference is a continuation of TERENO International Conference – held in 2014 (Bonn) and in 2018 (Berlin) – with support from the European research infrastructure eLTER (Long-Term Ecosystem, Critical Zone and Socio-Ecological Research Infrastructure).

▶ OZCAR-TERENO Conference

* The original date in fall 2020 was postponed due to the COVID pandemic. The new target date is also provisional, pending possible restrictions.

SUSTAINABLE USE OF GRASSLAND SOILS

SUSALPS project investigates the Alps and Alpine foothills in a changing climate

Flowering meadows and pastureland are characteristic of the Alps and its foothills, but climate change and intensive land use pose significant threats to these grassland ecosystems. As part of the SUSALPS project, researchers are developing more sustainable forms of land use to support the soil's natural ability to mitigate climate change.

With a total area of over one million hectares, grassland ecosystems are widespread in the Alps and Alpine foothills of southern Germany. These grasslands not only serve an important economic function by providing fodder for dairy and cattle farming; they also perform a range of important ecosystem services such as carbon and nitrogen storage, water retention, erosion protection as well as biodiversity. However, changes in climate, land use and grassland management currently threaten their ability to perform these many functions. The aim of the SUSALPS project ("Sustainable use of alpine and pre-alpine grassland soils in a changing climate") is to improve our knowledge of current/future climate and land-management factors and how they impact the important ecosystem functions performed by grasslands. The project also takes into account socio-economic factors in the region. On the basis of field and lab data, and supported by biogeochemical and economic modeling, SUSALPS project partners are working with farmers in the region to develop sustainable forms of land use and management for the grasslands.

For its work, SUSALPS also relies on grassland measuring sites within TERENO's Pre-Alpine observatory, including measurement systems along an altitude/climate gradient within the Ammer River catchment provided by the Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT/IMK-IFU) since 2010. TERENO also benefits from the use of its infrastructure and data, since it helps widen the spectrum of TERENO measurement sites and research topics.

In addition to KIT/IMK-IFU, other SUSALPS project partners include the Technical University of Munich (TUM), University of Bayreuth, University of Würzburg, the Helmholtz Centre Munich, as well as the Bavarian State Research Center for Agriculture (LfL). The interdisciplinary project is one of 11 collaborative projects within the BonaRes ("Soil as a sustainable resource for the bioeconomy") research initiative funded by Germany's Federal Ministry of Education and Research.

▶ SUSALPS – Sustainable use of alpine and pre-alpine grassland soils in a changing climate

▶ BonaRes – Soil as a sustainable resource for the bioeconomy

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eLTER RI: TWO NEW RESEARCH PROJECTS

The EU is funding two new projects for the further development of eLTER RI, the integrated European long-term ecosystem, critical zone and socio-ecological Research Infrastructure, in which TERENO is also involved. The EU financing, totaling 14 million, will allow eLTER to make significant progress organizationally and in terms of research being conducted at eLTER sites and platforms. The current plan is to launch the infrastructure in 2024.

eLTER RI

INTEGRATED EUROPEAN LONG-TERM ECOSYSTEM, CITICAL ZONE AND SOCIOECOLOGICAL RESEARCH INFRASTRUCTURE

The eLTER PPP (Preparatory Phase Project) will manage the operational, technical and strategic development at the approx. 250 eLTER sites throughout Europe. The sites will investigate and assess the impact of climate change on ecosystem services on a European scale. The goal is wide-scale and systematic coverage of major European terrestrial and freshwater environments as well as socio-ecological zones. The infrastructure will include both larger multidisciplinary platforms as well as smaller research sites. TERENO, which forms an important component of the infrastructure, has been involved in the development of eLTER RI for many years and is also involved in both research projects, with the Helmholtz Centre for Environmental Research – UFZ coordinating the eLTER PPP.

eLTER PPP project partners also want to develop and establish harmonized methods and research approaches. Another important goal is to improve access to data and provide comprehensive support to diverse user groups – from researchers to policy-makers.

In preparation for the launch, the Advanced Community Project eLTER PLUS will be conducting detailed performance tests of the emerging eLTER RI to challenge, assess and strengthen its operation, with the goal of combining the best knowledge and expertise with the best infrastructure. eLTER PLUS will also look to optimize and promote the use of knowledge and infrastructure by the various user communities.

eLTER PLUS results are thus considered an important contributor to the eLTER PPP project – in particular, to help understand what researchers will require of the eLTER research infrastructure, to facilitate coordination and agreement on environmental research standards, and to provide central services. All of these aspects are essential for the sustainable, pan-European operation of eLTER RI, in which a total of 34 partners from 24 countries are involved. “eLTER PLUS and eLTER PPP pave the way for a new kind of trans-disciplinary research – something that is urgently needed in today’s world with our ecosystems increasingly at risk,” says eLTER PLUS Coordinator and member of the TERENO Advisory Board Prof. Jaana Bäck from the University of Helsinki, Finland.

▶ eLTER RI

NEW MEMBERS

The TERENO Scientific Steering Committee (SSC) welcomes three new members. After Dr. Theresa Blume and Assistant Professor Susanne Liebner from the Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ) joined the committee earlier this year, they are now joined by a third new member: Dr. Nadine Rühr from the Karlsruhe Institute of Technology’s Institute of Meteorology and Climate Research (IMK-IFU). SSC responsibilities include defining TERENO objectives and priorities, and making decisions on collaborative projects with other institutions.

Nadine Rühr heads IMK-IFU’s Emmy Noether Research Group “Plant Ecophysiology” which investigates the impact of climate change on forests, with funding from the German Research Foundation (DFG). One of Rühr’s focus areas is stress reactions in trees, with the goal of better gauging the long-term impact of extreme droughts on forest carbon and water cycles.

Susanne Liebner is Assistant Professor for Molecular Environmental Microbiology at the University of Potsdam and GFZ Potsdam. At GFZ she leads the working group “Microbial carbon dynamics in the climate system” which focuses primarily on the microbial communities of the terrestrial surface and subsurface, and how they drive the formation and consumption of greenhouse gases such as carbon dioxide and methane. Her research focuses mainly on carbon cycle microbial processes in permafrost and peat bogs.

Theresa Blume heads the Hillslope and Ecohydrology Working Group at GFZ and is Scientific Spokesperson for TERENO’s Northeastern German Lowland observatory. Her research focuses on the hydrological processes of hillslopes and catchments, for which she combines the latest experimental methods, sensor technology and computer simulations.

EVAPOTRANSPIRATION – MORE HAPPENING AT NIGHT THAN YOU THINK!

The transpired water from plants and the evaporated water from soils, known as evapotranspiration, is – after precipitation – the second largest flux in the global terrestrial water cycle. While evapotranspiration occurs mainly during the day, recent investigations led by Jülich researchers Dr. Jannis Groh and Dr. Thomas Pütz suggest that the land surface gives off significant amounts of water at night, too.

Jannis Groh (r.) and Thomas Pütz at the SOILCan lysimeter station in Selhausen

Past research has devoted little attention to nighttime evapotranspiration. In principle, nighttime evapotranspiration can be predicted using models that use meteorological data. However, due to the lack of long-term observations, their verification is limited so far. As a result, prediction and measurements of nighttime evapotranspiration pose a major challenge to simulating land surface hydrological processes.

"With the help of highly temporally resolved and precise data from TERENO's SOILCan lysimeter network – gathered between 2013 and 2016 – we were able to quantify the amount of evapotranspiration between sunset and sunrise for two grassland ecosystems in western Germany. We found that nighttime evapotranspiration ranged between 3.5% and 9.5% of annual daytime evapotranspiration," reports Jannis Groh. Nighttime evapotranspiration occurred mainly during wet surface conditions and was positively correlated with wind speed. "This suggests that nighttime evapotranspiration at these locations is largely related to evaporation from wet canopy and soil surface conditions," says Thomas Pütz. The researchers also found that hot days during the observation period significantly increased average nighttime evapotranspiration rates. "Overall, our results suggest that nighttime evapotranspiration can be observed with lysimeters and is an important component in the water balance of grassland ecosystems," says Groh.

J. Groh, T. Pütz, H. H. Gerke, J. Vanderborght and H. Vereecken (2019). *Quantification and Prediction of Nighttime Evapotranspiration for Two Distinct Grassland Ecosystems. Water Resources Research 55 (4), pp. 2961-2975.*

▶ DOI: 10.1029/2018WR024072

DIFFERENCES IN NITROUS OXIDE FORMATION

Hydroxylamine (NH_2OH) and nitrite (NO_{2^-}) are important intermediates of the nitrogen cycle in soils. They play a crucial role in the loss of nitrous oxide (N_2O), also known as laughing gas. To better understand their roles, German and Chinese researchers investigated soil samples taken from TERENO'S Eifel/Lower Rhine Valley observatory. Their insights could help farmers determine optimal times for fertilization as a way to minimize nitrogen loss from agricultural soils.

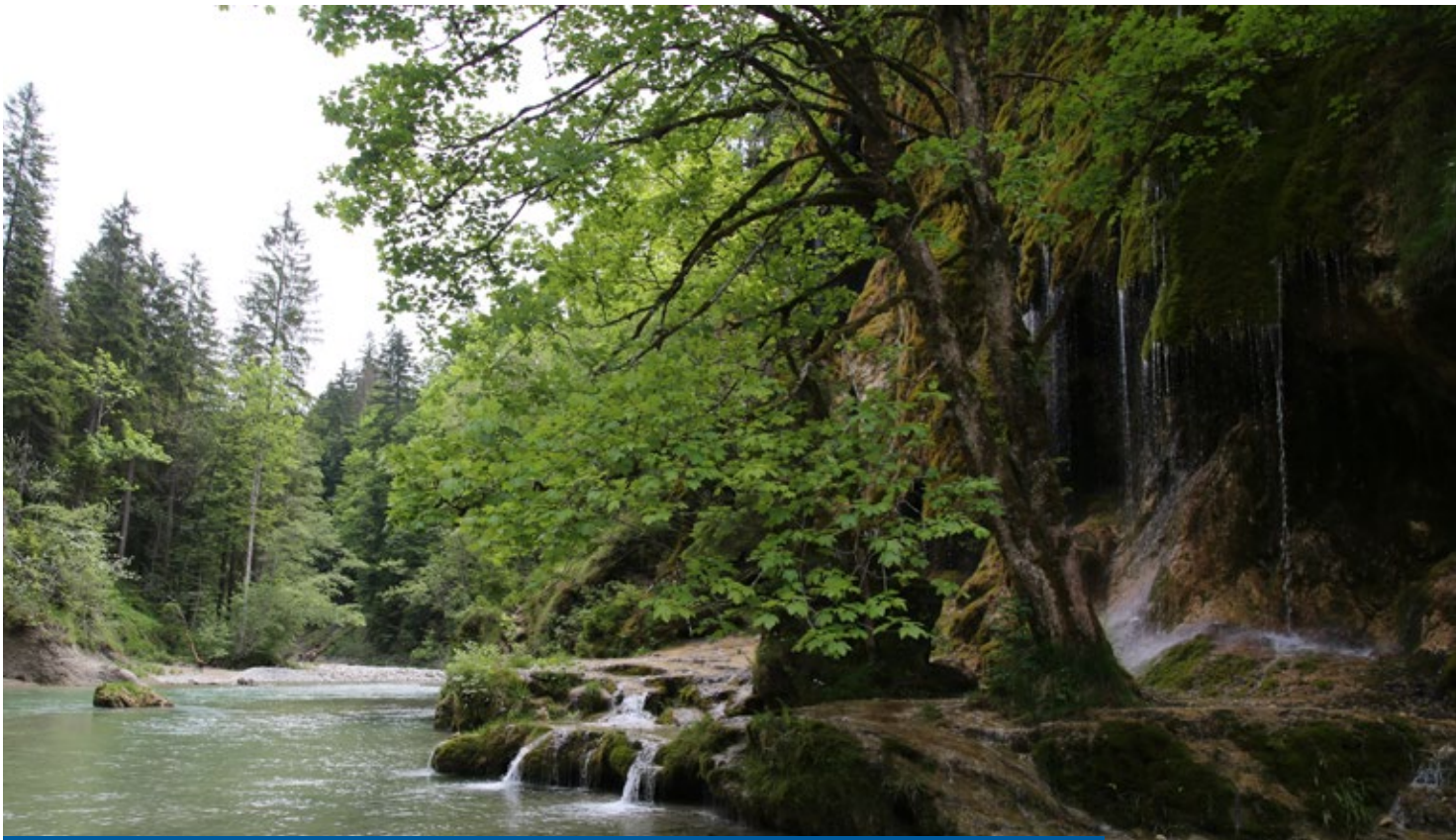
The nitrogen cycle involves complex processes in which nitrogen-containing compounds are converted into other nitrogenous substances. In soil-based nitrogen cycle processes, microorganisms play an important role, including bacteria, fungi and archaea, several of which require no oxygen.

Prof. Nicolas Brüggemann and his team at Forschungszentrum Jülich, along with Dr. Shurong Liu, currently at the University of Vienna, and Prof. Michael Schloter at Helmholtz Center Munich, had collected soil samples from three ecosystems within TERENO's Eifel-Rur research area: grassland, arable land, and forest with a riparian zone. In the lab, they investigated N_2O formation under different conditions. One portion of the samples, for example, was stored for a week without oxygen (anoxic pre-treatment) and the other with oxygen (oxic pre-treatment). Half of each portion was also irradiated with gamma irradiation to kill any microorganisms.

Anoxic pre-treatment decreased N_2O production from hydroxylamine significantly, while increasing N_2O production from nitrite. The results suggest that hydroxylamine plays an important role for abiotic N_2O formation in soils (i.e., the last step of N_2O formation not performed by microorganisms), especially in soils with low organic carbon (C) and high manganese (Mn) content. The effect of nitrite was important mainly during biotic N_2O production (i.e., the last step of N_2O formation performed by microorganisms), particularly after longer anoxic periods (without oxygenation). The effects of nitrite on N_2O production were strongly correlated to ammonium (NH^{4+}) content in soils. The researchers also found that the addition of nitrite induced the largest N_2O production in the grassland soil, while the addition of hydroxylamine increased N_2O emissions the most from the arable soil.

Shurong Liu et al. (2019). *Hydroxylamine Contributes More to Abiotic N_2O Production in Soils Than Nitrite.* Frontiers in Environmental Science, 17 April 2019.

▶ DOI: 10.3389/fenvs.2019.00047



The Ammer River, here at the Schleier falls between Oberammergau and Peissenberg, is part of TERENO's Pre-Alpine observatory; its catchment covers some 600 square kilometers.

SIMULATING FUTURE RUNOFF IN MOUNTAINOUS TERRAIN

The ability to estimate changes in alpine river runoff under future climate conditions is a key piece of the puzzle when it comes to planning adaptation and mitigation strategies. Dr. Gerhard Smiatek and Prof. Harald Kunstmann from the Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT/IMK-IFU) investigated the use of small-scale hydrological climate change impact assessment as a way to generate such forecasts, relying on data from the Ammer River catchment in TERENO's Pre-Alpine observatory. The results suggest that extreme runoffs between 2071 and 2100 could increase by roughly 10% compared to runoffs between 1975 and 2005. At the same time, Smiatek and Kunstmann found substantial uncertainties in the hydrologic analysis, particularly when using precipitation values based solely on climate models.

"Alpine catchments pose special challenges," says Kunstmann. "The large elevation differences over the course of a river mean that precipitation events can cause very fast runoff. These streamflows are particularly sensitive to climate-related changes in both the number of precipitation events and their intensity. It increases the flooding potential of extreme events, for example." Simulations, coupled with climate-hydrological models, provide a way to quantify the runoff. "The TERENO observatory, with its instrumentation and location along the Ammer River, is particularly well-suited for developing and validating the models," explains Kunstmann.

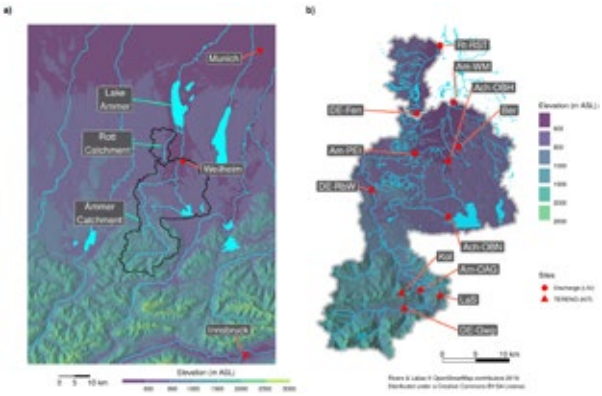
For their investigation, Smiatek and Kunstmann applied the hydrological simulation model WaSiM-ETH – which takes into account precipitation, temperature, radiation, wind and humidity – and combined it with climate simulation data from the EURO-CORDEX research initiative. They used data from seven different CORDEX regional climate models to reproduce runoff events from 1975 to 2005 and simulate future runoffs.

"We found that the CORDEX data, with its spatial resolution of 10 km, is limited in its ability to derive future extreme values in catchments with complex terrain, such as the Ammer catchment," reports Smiatek. WaSiM simulations relying solely on simulated climate data significantly underestimated extreme runoffs. At the same time, WaSiM did a relatively good job of reproducing observed runoff when using observed precipitation data. "The main issue is the climate models and their limited ability to reproduce precipitation levels," explains Smiatek. Precipitation modeling with fully-coupled, compartment-crossing regional atmospheric and hydrological modeling, i.e. a single modelling system allowing feedback between compartments, is the subject of ongoing research at KIT/IMK-IFU. Here, too, TERENO instrumentation is essential to enabling comprehensive validation.

G. Smiatek and H. Kunstmann (2019). *Simulating Future Runoff in a Complex Terrain Alpine Catchment with EURO-CORDEX Data. Journal of Hydrometeorology,* Vol. 20, Issue 9.

▶ DOI: 10.1175/JHM-D-18-0214.1

WHICH MODEL REPRODUCES EXCHANGE PROCESSES MORE REALISTICALLY?



Hydrol. Earth Syst. Sci., 24, 2457–2481, 2020, https://doi.org/10.5194/hess-24-2457-2020, © Author(s) 2020. This work is distributed under the Creative Commons Attribution 4.0 License.

Because hydrological processes, such as water distribution or storage in the soil, influence land surface conditions, they also affect the processes of water, gas and energy exchange with the atmospheric boundary layer – processes that researchers try to reproduce as realistically as possible in their models. In a study performed by German and Italian experts, researchers compared two different modeling approaches: a fully coupled atmospheric-hydrological model and an uncoupled regional atmospheric model.

"Fully coupled means that a modeling system simulates both atmosphere and land surface, including water redistribution through hydrological processes, and can therefore consider more complex interactions between the two. Regional atmospheric models, on the other hand, typically use a greatly simplified representation of land surface processes and depict the water cycle only incompletely," explains lead researcher Dr. Benjamin Fersch from the Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT/IMK-IFU).

As part of their study, the team ran simulations with the traditional regional atmospheric model WRF (Weather Research and Forecasting Modeling System) and with the hydrologically enhanced model WRF-Hydro. WRF-Hydro closes the regional water cycle in the simulation, since it simulates both overland routing of surface runoff as well as channel (discharge) routing. Researchers then validated the results by comparing them to a comprehensive dataset of measurements by TERENO's Pre-Alpine observatory for the Ammer catchment in Bavaria.

"The fully coupled model slightly outperformed the classic WRF model in mimicking the observations. Incorporating the terrestrial hydrological processes resulted in more soil moisture and increased evapotranspiration overall as compared to the uncoupled model. At the subcatchment level, the differences were most notable with regard to evapotranspiration and so-called infiltration excess, i.e. land surface runoff following heavy rains. Differences in simulated precipitation, on the other hand, were minimal," says Benjamin Fersch, summing up the results of the study.

B. Fersch, A. Senatore, B. Adler, J. Arnault, M. Mauder, K. Schneider, I. Völksch and H. Kunstmann (2020). *High-resolution fully coupled atmospheric-hydrological modeling: a cross-compartment regional water and energy cycle evaluation, Hydrology and Earth System Sciences, 24, 2457–2481.*

▶ DOI: 10.5194/hess-24-2457-2020

The Selhausen site from above

TESTING A POTENTIAL SATELLITE MISSION

In summer 2019, TERENO's Selhausen site hosted the SARSense airborne measurement campaign funded by the European Space Agency (ESA). Involving three measurement aircraft, drones and numerous measurement instruments on the ground, SARSense was a demonstration campaign to test the potential (and specifications) of the ESA candidate mission ROSE-L, which could expand on ESA's existing Copernicus satellite program and augment the radar observation system for Europe.

ROSE-L would carry a polarimetric L-band SAR (Synthetic Aperture Radar). Europe's Copernicus Sentinel-1 mission, launched in 2014, is fitted with a C-band, which works in another microwave frequency range. "Unlike C-band, the L-band signal can penetrate through many natural materials such as vegetation, dry snow and ice, which would allow ROSE-L to provide additional information. The combination of the two signals could be used to support forest management by delivering more precise information about forests, to monitor subsidence and soil moisture, and to identify crop types for precision farming and food security," explains Dr. Carsten Montzka from the Institute of Bio- and Geosciences at Forschungszentrum Jülich, which was involved in the measurement campaign along with Italy's National Research Council CNR and the Dutch company MetaSensing.

Using the extensive measurement infrastructure available at TERENO'S Eifel/Lower Rhine Valley observatory, SARSense project partners were able to measure important reference data such as soil moisture, soil temperature and vegetation height. To achieve comprehensive spatial measurements, SARSense was combined with additional campaigns, including the MOSES Heatwaves campaign, FLEXSense (in support ESA's Earth Explorer FLEX mission), as well as campaigns to support ESA's Sentinel Expansion candidates. "Thanks to SARSense, we are now able to quantify the difference between two radar frequencies used to measure vegetation and soil properties, even for the kind of drought conditions we saw in summer 2019," says Carsten Montzka, summing of the positive results of the campaign.

More than half of Germany's 561 wild bee species are considered endangered.

AID FOR AT-RISK POLLINATORS

Wild pollinators such as bees continue to decline in numbers. According to the world biodiversity council IPBES, the decline applies to abundance, occurrence, as well as diversity. Climate change is considered among the causes. Targeted land management practices, however, could increase the resilience of wild bee communities.

Pollinators such as wild bees provide a key ecosystem service, and their decline poses a threat to both wild and crop plants. Among the most important drivers of pollinator decline are habitat loss and degradation, intensive agriculture, climate change, disease, and alien species. At the same time, these drivers may interact with one another to either reinforce or weaken the response of wild pollinators to any one driver. "It might be possible to use such interactive effects to improve adaptability to climate change," says Dr. Oliver Schweiger from the Helmholtz Centre for Environmental Research – UFZ, who, together with fellow UFZ colleagues, investigated the impact of climate change on pollinators.

Their study was based on monitoring data from six sites in TERENO's Harz/Central German Lowland observatory. The UFZ researchers examined 95 local wild bee communities weekly over a period of three years in six agricultural landscapes. As expected, semi-natural areas had a positive effect on wild bee abundance, richness and community stability, while warming temperatures had a negative effect. "The most remarkable finding was that bees in more natural habitats were significantly more resilient vis-à-vis changing climates," reports Schweiger.

For the researchers, this suggests that increasing the amount and heterogeneity of semi-natural habitats in agricultural landscapes might enhance the resilience and adaptability of local wild bee communities. According to Schweiger, the potential benefit is substantial: "Agricultural areas in Europe are characterized by extremely low amounts of semi-natural areas. In about 45% of agricultural landscapes in central Germany, for example, the amount of semi-natural habitat is less than 17%." Below this critical threshold, explains Schweiger, wild bee communities face increasingly higher risks from global warming. This means that the EU Common Agricultural Policy's target of 7% Ecological Focus Areas falls too short for pollinators. "The target needs to be raised to at least 17%," says Schweiger.

O. Schweiger et al. (2019). *Minimising Risks of Global Change by Enhancing Resilience of Pollinators in Agricultural Systems.* In: M. Schröter, A. Bonn, S. Klotz, R. Seppelt and C. Baessler (Hrgs.) Atlas of Ecosystem Services, pp. 105-111.

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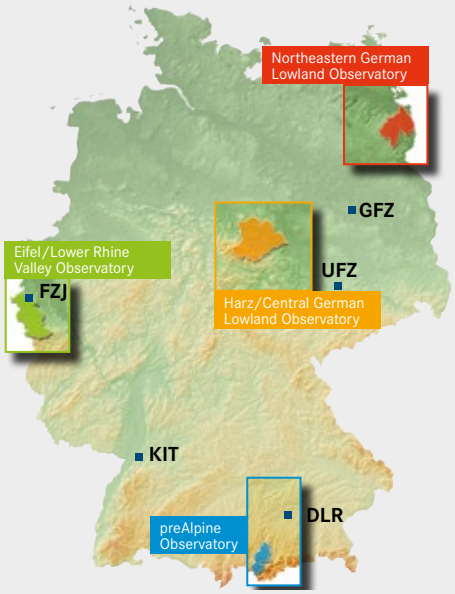

FZJ Forschungszentrum Jülich (Coordination)

DLR German Aerospace Center

KIT Karlsruhe Institute of Technology

UFZ Helmholtz Centre for Environmental Research

GFZ Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences

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