Burn damage
in the rainforest

This summer, there were more forest fires in Brazil than virtually any on record. **Susan Trumbore**, Director at the **Max Planck Institute for Biogeochemistry** in Jena, is looking at the consequences that the immense loss of rainforest has on the local, as well as global climate. She also examines the likelihood of a forest recovering from a fire. If only it is given the chance.

TEXT **TIM SCHRÖDER**

The rainforest in Brazil has been burning for decades, over and over again. In many places, farmers are setting the forest on fire, while elsewhere, clearing is taking place on behalf of beef barons. The goal is to obtain new farmland to grow soy, mainly for fattening animals in Brazil and other countries. Plenty of cleared land is also home to grazing cattle. Many farmers also burn their stubble fields after the harvest, not taking into account that sparks can cause wildfires.

Reports about crop fires are nothing new. However, particularly terrifying pictures appeared this summer, as the fires reached catastrophic proportions in August. Analyzing satellite images, the Brazilian National Institute for Space Research, the INPE, found fires to have increased by about two-thirds in the region, compared to the same time period in previous years, with more than 45,000 fires in total.

The fact that most of these fires were not caused by particularly severe drought is cause for concern. The past few summers had been even drier. This increase can be attributed to economic interests: most fires broke out on privately owned land and close to rural settlements. Brazilian experts assume that there has been an increase of fire-based forest clearing in these areas. The most alarming aspect is that there has been a massive increase in the number of fires even in public state forests and conservation areas.

Deforestation in the Amazon rainforest has dramatic consequences. Countless plants and animals are losing their habitat, and it is quite likely that hitherto unknown plant and animal

Fire detectors in space: the fires in the south of the Amazon Basin are particularly striking in satellite images from the Nasa Earth Observatory, but those in other parts of South America are also clearly visible.

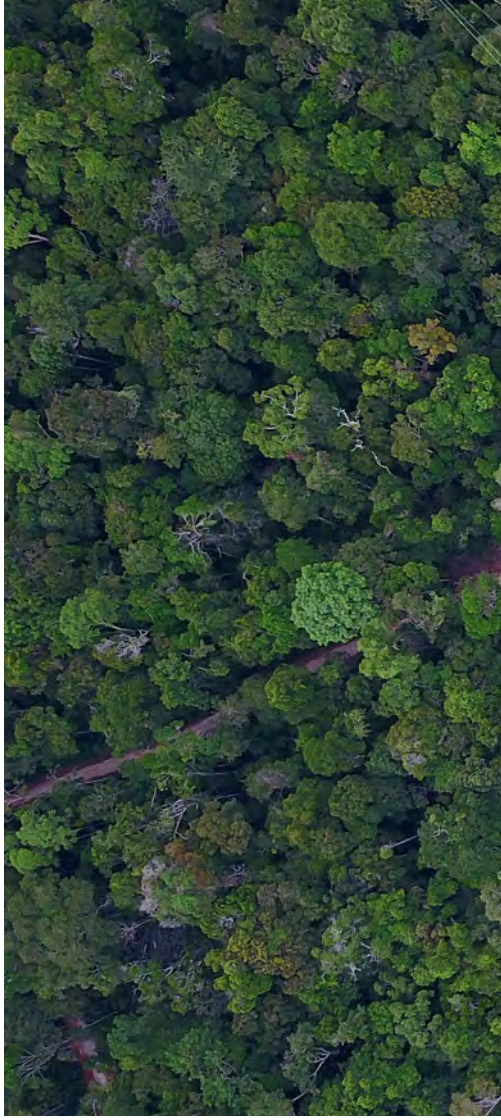
Photo: NASA/EOSDIS

species are being wiped out. The loss of forest is also expected to have an impact on the climate across large parts of South America, and possibly even on a global scale. The Earth system researcher Susan Trumbore, Director at the Max Planck Institute for Biogeochemistry in Jena, wants to gain a comprehensive understanding of the consequences this overexploitation has on nature.

She examines not only the impact on biodiversity after forests have slowly begun to recover years after a fire. She also addresses the question as to what extent the remaining forest has become more vulnerable to further disturbances, such as drought or windthrow, as farmland advances. She is collaborating with Brazilian researchers to explore how deforestation impacts regional and global climate, as well as the ways in which the forest reacts to such climate change. "We do not have sufficient data at this point to accurately illustrate the impact of the Amazon region in climate models," Susan Trumbore explains. "We would like to contribute to improving climate models in this respect."

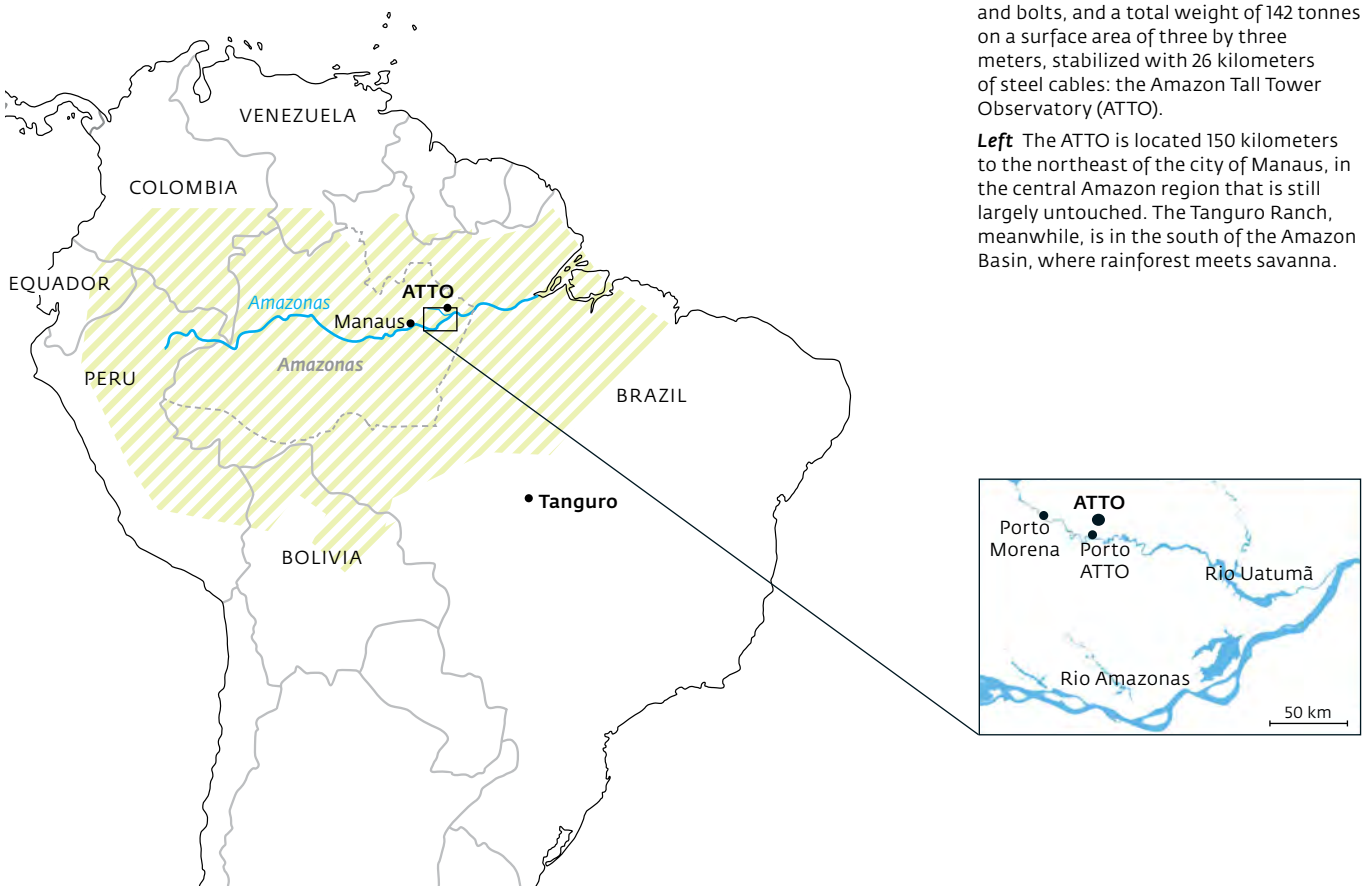
THE FOREST STILL ABSORBS THE FIRES' CARBON DIOXIDE

With regard to the local and regional climate, it is of particular importance that enormous amounts of water evaporate in the forest of the Amazon Basin. This has a cooling effect on the forest



Top 15,000 components, 24,000 screws and bolts, and a total weight of 142 tonnes on a surface area of three by three meters, stabilized with 26 kilometers of steel cables: the Amazon Tall Tower Observatory (ATTO).

Left The ATTO is located 150 kilometers to the northeast of the city of Manaus, in the central Amazon region that is still largely untouched. The Tanguro Ranch, meanwhile, is in the south of the Amazon Basin, where rainforest meets savanna.



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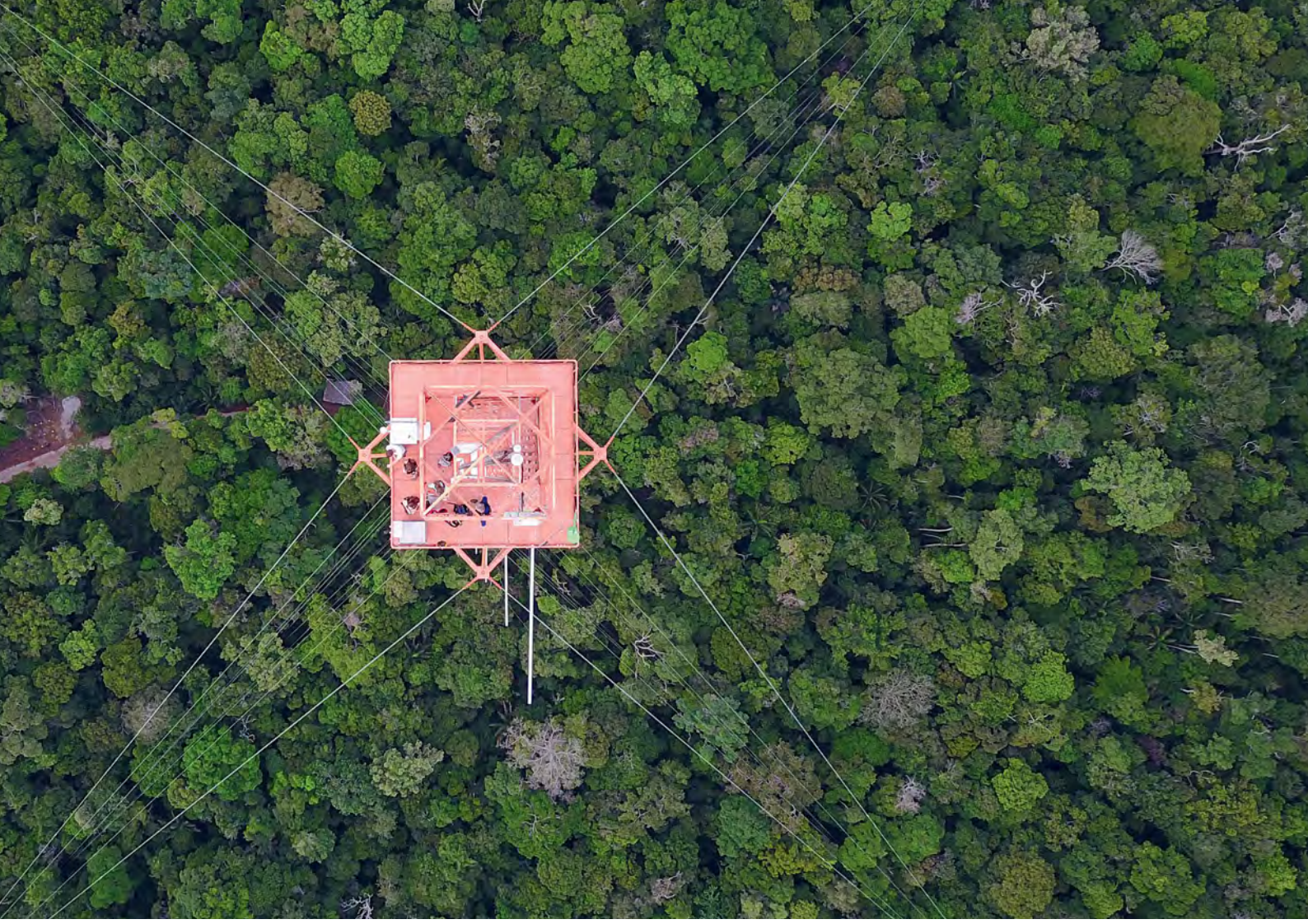

Photo: Achim Edtbauer / MPI for Chemistry

and its environment, and half of this water is returned to the area as rain. A part of the clouds that form move on, however, providing rainfall for large parts of South America.

Scientists agree that owing to its sheer size, the Amazon region has a significant influence on global climate. The Amazon Basin that feeds the Amazon River covers an area of around seven million square kilometers – about twenty times the size of Germany. Currently, 80 percent is still covered by forest. About one-third of the amount of carbon contained in the Earth's atmosphere at the start of the industrial revolution is still stored in this area today.

Today, the forest is still able to absorb the carbon dioxide that is released through fire clearance in Brazil. However, it can no longer filter greenhouse gases from the atmosphere that are generated elsewhere as a result of the use of fossil fuels. If the deforestation that had initially slowed down after 2003, but increased again in 2019, accelerates further, it could even happen that, on balance, greenhouse gases are released in the Amazon region.

Conversely, it is also likely that global warming will change the forest and its ability to absorb greenhouse gases. Scientists question whether the rainforest will survive a global rise in temperature by more than two degrees Celsius, since there is currently no rainforest anywhere in the world where temperatures are that high. This means that the Amazonian forest might disappear due to climate change. "It is impossible at this point to predict what a warming of the Earth by two degrees Celsius or more would mean," says Susan Trumbore. "How are habitats, the chemical and physical processes between the forest and the atmosphere and gas exchange going to change? And how are these changes going to affect our global climate?"

To be able to assess the feedback effect between climate change and the shrinking rainforest, scientists first need to understand the role that an intact forest plays with regard to the global climate. This is why, for the past few years, Susan Trumbore and her team have been involved in an extraordinary large-scale research project: ATTO, the Amazon Tall Tower Observatory, an ensemble of three slim steel framework towers, the largest of which, at 325 meters, is taller than the Eiffel Tower.

THE EFFECTS OF DAMAGE TO THE TREE POPULATION

The observatory is located deep in the rainforest, about 150 kilometers to the northeast of the city of Manaus. The journey takes several hours, and part of the distance is covered in boats on a river. "The area is unique," says Susan Trumbore. It is far from any cities or villages. It has the purest air anywhere on the planet. Here, it is possible to take very accurate measurements of the exchange of substances between the untouched forest and the atmosphere. >

"This is pretty much the last place on Earth where we can examine the original impact of a large intact forest," explains Trumbore.

Provided, that is, that there are no fires on the southern edge of the Amazon combined with unfavorable wind conditions. This causes soot particle aerosols to travel northwards, for example. As water vapor is prone to condensing on such aerosols, causing droplets to form, it is feasible that fires in the south can have an impact on cloud formation and rainfall across the entire Amazon Basin. However, experts are not yet able to tell whether this will lead to more rain or to any changes in the rainfall areas.

The measurement towers were constructed step by step by Brazilian and German research institutions, including the Max Planck Society with funds from the Federal Ministry of Education and Research. They are full of devices for measuring carbon dioxide, methane and other substances, as well as the amount of aerosols contained in the atmosphere. The researchers use sophisticated methods to measure and calculate which amounts of which substances are exchanged between the forest and the air. Other equipment is used to measure wind direction and speed, as well as solar irradiation above the forest.

The researchers working with Susan Trumbore at ATTO not only monitor substance and energy exchange between the forest and the atmosphere. They also examine the effects that damage has on the tree population. A few years ago, entire clusters of trees near the observatory were knocked over by thunderstorms. This created clearings in the otherwise dense forest that provide ideal research sites, the biggest of which is 28 hectares in total – about the size of 40 soccer fields.

RESEARCH AREA IN A BRAZILIAN HOTSPOT

Susan Trumbore and her team are able to conduct research on a wide range of aspects here, such as the rate at which trees decompose and to what extent they release their stored carbon as they do so. Severe storms may occur more frequently due to climate change; storms that are strong enough to uproot trees by the dozen. The wood decomposes and the forest's biomass is reduced as time goes by.

Susan Trumbore and her team members are also examining the speed at which the affected forests regenerate. They have found that evaporation and photosynthesis recover within just a few years, as these functions are taken over by rapidly growing shrubs and trees. It takes decades, however, for the same amount of biomass that

Left Susan Trumbore explores the interdependencies of the Amazonian rainforest and the climate.

Top Advancing agriculture: large forest areas have to make room for farmland at the edge of the Amazon Basin. This has caused a hotter and drier local climate, despite the fact that the remaining forest still has a cooling effect and provides the conditions for rain.

Photo: Paulo Brando

Photo: Paulo Brando

was contained in the old tree population to reform. It takes even longer for the forest to become nearly as biodiverse as it was before.

Susan Trumbore compares the results from the ATTO area with measurements taken in a second region in Brazil, where she has been conducting research for a number of years now. This research site, the Tanguro Ranch, is located in a Brazilian hotspot, where the forest meets cleared savannas and farmland, about 2,500 kilometers to the south of Manaus in the state of Mato Grosso, the driest part of the Amazon Basin. The transition zone between dense Amazonian forests and savannas is typical of the region. The land on the Tanguro Ranch is intensively farmed. In recent years, there have been more clearances in this area than anywhere else.

Researchers analyze how the local climate is changed by this loss of trees, but they also take a look at global climate effects caused by deforestation. There is already evidence that the intense deforestation is causing the climate to become even hotter and drier in this region, which already experiences a five-month dry season.

In addition, scientists are examining the extent to which the remaining forest on the edge of the savanna is affected – and whether it stands a chance of recovery on land that has been cleared. In order to answer these questions, a team of experts from Brazil, Germany and the Woods Hole Research

Underestimated threats: fires on forest floors are invisible to satellites. Based on smoke measurements, ATTO can register these fires, too (left). Grasses can spread on cleared land and invade adjacent forests (right). They can grow even taller than Susan Trumbore, and they take light away from seedlings. They therefore hinder the forest's regeneration and they also make the forest more vulnerable to fire.

Center in the U.S. launched an unusual project in the early 2000s: fire experiments carried out in three forested 50-hectare areas in the transition zone to the savanna.

Between 2004 and 2010, the researchers set one plot on fire every year, and another one only once every three years. The third plot remained untouched. They then allowed the forest to recover. In the meantime, they analyzed the climate conditions and substance flows on the burned plots, and compared these to corresponding data from a nearby soy field, from the edge of the forest, and from a measuring station located deeper in the forest.

The researchers found that the fires did not overly affect the forest in humid years. In dry years, however, and these have become increasingly common in recent years, the fire burned a large number of trees. As soon as the fire had created large gaps, the surrounding forest thinned out, as it had become more vulnerable to wind, and because the more open forest dried out more quickly. This effect continues to this day, eight years after the last fire. A noticeable number of trees are still dying from the consequences of the fires. Furthermore, the now more open forests have become invaded by various grasses. These prevent trees from growing back, as they take away light and nutrients from seedlings.

FIRES ARE MAKING FORESTS MORE VULNERABLE

Measurements show that as in the ATTO region, trees that are growing back can perform vital ecosystem services after just a few years, especially compared to a dry soy field. Evaporation and photosynthesis, and therefore the absorption of carbon from the air, had normalized once again by 2017. Evaporation also has a cooling effect in this hot region, and this shows how important it is to conserve forests, at least in part, in areas used for agriculture. However, significantly less carbon is now stored on these plots.

Ten years after a fire, the forest has not fully recovered: a young, bushy forest that grows after a fire does not provide the conditions for the same ecosystem as the original one. Even worse: in some areas, the forest may disappear completely after a fire. "We can observe that fires make forests, and particularly their edges, more vulnerable," says Susan Trumbore and goes on to explain that a main driving question of the research is to find out whether repeated fire will eventually turn the forest into savanna. "We assume that there are tipping points, beyond which a forest is no longer able to recover by itself and will disappear," she explains. The exact tipping point has not been identified to date.

This is why Susan Trumbore and her team also want to find out which species of trees stand a chance of survival in the increasingly dry and hot region around the Tanguro Ranch. "It is quite possible that species that grow back quickly will also die again quickly," she says. "We do not know yet

Photo: Paulo Brando

Photo: Paulo Brando

which species have what it takes to form a new, robust forest under these tougher climatic conditions."

Susan Trumbore was also shocked by the extent of the fires that afflicted this region a few months ago. However, she points out that the land that is cleared every year has somewhat decreased in recent years. Significantly bigger forest areas were still disappearing every year in the early 2000s. The scientist cannot tell to what degree the devastating fires of 2019 are linked to the policies pursued by the Brazilian president Jair Bolsonaro. "The long recent drought period is likely to have contributed to this, too."

At any rate, in her view, Brazilians are not solely responsible for conserving the Amazonian rainforest. "People from industrial nations are good at telling others how to do it right. At the end of the day, we citizens of industrial countries have contributed to creating this situation," she says. Around 80 percent of soy imported to Germany comes from South America, according to the environmental foundation WWF. However, China is the biggest importer of soy, accounting for 60 percent of global production. About half of this is produced in Brazil.

The predecessors of president Bolsonaro, Luiz Inácio Lula da Silva and Dilma Rousseff, had promoted improved farming methods to exploit the soil more effectively, and in so doing to increase production and reduce the pressure on the forest. Jair Bolsonaro, however, is promoting an expansion of the areas used as farmland. Susan Trumbore believes that import nations are partially responsible: "The situation is not going to change unless they urge Brazil to treat the remaining forest with greater care."

It goes without saying that people in industrial countries must pay more attention to the origin of resources used to make the food that they buy – and promote products and practices that recognize the value of rainforests. After all, finger-pointing is not going to save the Brazilian rainforest from further destruction. ◂

SUMMARY

- **In summer 2019, an extraordinarily large number of fires raged in the Amazonian rainforest. Many of these were started deliberately and were boosted by increasingly dry conditions.**
- **Teams working with the Max Planck researcher Susan Trumbore are examining the ways in which the rainforest and the climate affect each other, at both the Amazon Tall Tower Observatory (ATTO) in the heart of the rainforest and on the Tanguro Ranch in the State of Mato Grosso.**
- **In areas that have been cleared, and where much less water evaporates, it is getting hotter and drier. This also has an impact on rainfall in other areas, as the Amazonian rainforest determines the water balance of the entire region. The CO_2 that is released through clearing has an impact on the global climate.**
- **If the forest is allowed to grow back on cleared land, the exchange of carbon dioxide and water between the vegetation and the atmosphere can reach almost its original level after just a few years. However, far less carbon is stored in degraded forest, which remains more vulnerable to heat, drought and windthrow. This in turn can lead to further die-off and a rapid shift to a new stable state of savanna vegetation.**