Photo: Matthew Forrest

CLIMATE, EARTH, ENVIRONMENT

An attempt to rescue the savannahs

Impacts of climate change and adaptation strategies

By Andreas Lorenz-Meyer

Ecosystem protection and climate protection are not separate things. Rather, they belong together and must also be considered together, as a German-South African project involving Goethe University Frankfurt shows. It centres on landscapes with unique flora and fauna.

In the northeast of South Africa, near the border with Mozambique, lies one of the most famous nature reserves in the world: the Kruger National Park. Its vast grasslands with the occasional tree or bush are home to hundreds of species of birds, reptiles, fish and amphibians. There are 147 mammalian species in the savannah, including, of course, the "Big Five": lion, elephant, leopard, buffalo and rhinoceros. They attract over a million visitors each year and promise a spectacular experience in the wild.

However, the future of this semi-arid ecosystem, dominated by alternating rainy and dry seasons, is uncertain because climate change will presumably hit southern African very hard. Climate scenarios predict more drought and higher temperatures, especially for southwestern Africa. This will also affect savannahs such as the Kruger National Park. What does climate change mean for ecosystems? How can we preserve their immense biodiversity?

EMSAfrica, an interdisciplinary German-South African research project, is exploring these questions. In addition to the consequences of climate change, it is also looking at the effects of land use. The aim is to deliver sound scientific data that will help in the future to make the right decisions concerning adaptation to climate change and the sustainable management of ecosystems.

Climate change is shifting vegetation zones

EMSAfrica builds on the results of ArsAfricae, the predecessor project. Between 2014 and 2018, the Thünen Institute of Climate-Smart Agriculture in Braunschweig, Germany, set up six observation stations in South Africa, where, among others, land-atmosphere carbon dioxide exchange is measured. EMSAfrica is divided into six work packages. Thomas Hickler, Professor for Quantitative Biogeography at Goethe University Frankfurt and work group leader at the Senckenberg – Leibniz Institution for Biodiversity and Earth System Research, is responsible for work package 4, "Vegetation and Ecosystem Modelling for Climate Impact Assessment". Together with his team, he is studying how plants and animals are distributed on Earth. In addition, he is looking at ecosystem functions and the growth of forests: topics that are subsumed in English under the term "Ecosystem Ecology".

"Within the EMSAfrica project, we're trying to simulate changes in vegetation induced by climate change in the whole of southern Africa," explains Hickler. Here, the focus lies on possible shifts in vegetation zones, especially in the savannahs. Professor Guy Midgley from Stellenbosch University, Hickler's South African

Regular fires are important for preserving the open grassland of the savannah.

Photo: Maurizio De Mattei/Shutterstock

The EMSAfrica Project

The three-year EMSAfrica research project (Ecological Management Support for Climate Change in Southern Africa) is funded by Germany's Federal Ministry of Education and Research via the SPACES programme (Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa). Five German institutions are involved – besides Goethe University Frankfurt, the University of Bayreuth and the Thünen Institute of Climate-Smart Agriculture, as well as various South African researchers and institutions, including Professor Guy Midgley from the Department of Botany and Zoology at Stellenbosch University and Dr Gregor Feig from the South African Environmental Observation Network (SAEON). Carola Martens from Goethe University Frankfurt is completing her doctoral degree within the project, and Dr Simon Scheiter from the Senckenberg – Leibniz Institution for Biodiversity and Earth System Research is also a project partner. South African scholar Mulalo Thavhana is currently conducting research in Germany within an exchange programme of the German Academic Exchange Service. EMSAfrica combines various scientific disciplines and approaches: direct measurements of greenhouse gas, remote sensing, vegetation modelling, ecophysiological measurements of plants, socioeconomic studies, computer-based simulation models.

www.emsafrica.org

Marek Jakubík, cooperation partner at the Global Change Research Institute in the Czech Republic, is examining how much CO_2 the soil emits – through respiration by plant roots and microbial decomposition processes of organic material – in the Nama Karoo near Middelburg, an ecosystem of dwarf shrubs and grasses found only in South Africa and Namibia.
Photo: Carola Martens

colleague, describes their significance as follows: "From an economic perspective, these semi-arid grasslands are the basis primarily for sheep and cattle farming. In addition, they provide ecosystem services – water cycles, nutrient cycles, carbon storage. They are also special because they are so old and varied. Their biodiversity is extraordinary. There are many endemic species and genera and even entire families of animals and plants that are found only here."

Studying how the flora in the savannahs alters as climate change progresses is no easy feat. "The dynamics of these systems are determined by complex interactions between climate, grazing animals and regular fires," says Hickler. Nailing down this complexity calls for a powerful computer simulation model and many different observational data, from experimental field data to satellite observations. Model development is one of the main tasks of Hickler's research group. The ones used are often referred to as Dynamic Global Vegetation Models (DGVM) and are increasingly being developed by the international scientific community in collaboration. Hickler's research group is using two such models in the project. One of them was specifically adapted for the conditions in the tropical and subtropical grass-tree systems of Africa: the adaptive Dynamic Global Vegetation Model, in short aDGMV, originally developed by his Senckenberg colleague Simon Scheiter and Steven Higgins (University of Bayreuth).

Computer simulates vegetation

The model's capabilities are astonishing. "It can show how individual trees compete with each other for water and light," explains Hickler.

Photo: Vision2030, Wikimedia

Effectively, environmental conditions, above all climate, soils and land use, determine which plant species and characteristics manage to dominate, for example evergreen rainforest trees or deciduous savannah trees or grasses. The model takes into consideration a range of ecophysiological processes, such as photosynthesis, transpiration and carbon accumulation in roots or leaves. aDGMV can also illustrate the effect of fire on individual trees. Fires are a regular occurrence in the savannahs, which is why savannah trees are more fire-resistant than rainforest trees.

The model simulates many plant characteristics and processes, and plant height determines whether trees survive a savannah fire or not. aDGMV thus masters complex connections within the ecosystem. The model is parametrised with a wide range of data, such as measurements of the photosynthesis of various plants, results of field experiments including experimental fires, measurements of CO_2 exchange as well as satellite-based assessments of the vegetation's seasonal development.

That climate change will lead to extensive changes in southern Africa is clear. And there are already signs of what's in store for the savannahs, as Hickler says: "Some observations and our models suggest that these are increasingly overgrown with bushes, which threatens their unique biodiversity." The cause is probably also the increased CO_2 content of the atmosphere, which brings with it "a certain fertilisation effect".

More CO_2 leads to more plant growth

The background: more CO_2 in the atmosphere not only heats up the planet but also directly increases plant growth. This effect is known as CO_2 fertilisation. How intensive it is depends on the plant species, on how plants conduct photosynthesis. Bushes and trees are C3 plants. C3 because the first product of their photosynthesis has three carbon atoms. C3 plants have to close their stomata, through which they release water vapour, when it is very hot and dry. This protects them from drying out, but at the same time CO_2 can no longer enter their leaves, which the plants need for photosynthesis. The grasses of the savannah do not have this problem. They are among the rarer C4 plants, as during photosynthesis they first store CO_2 temporarily in a molecule with four carbon atoms and then concentrate it in special cells where the actual CO_2

IN A NUTSHELL

- In the EMSAfrica project, computer models simulate how South Africa's savannahs are changing as a result of climate change.
- Bushes and trees, which are increasingly displacing grass, are likely to benefit from the higher CO_2 content of the atmosphere. This might endanger many plant and animal species in the ecosystem.
- Artificial bushfires and smart management of land use, for example by planting crops, could help to counteract bush encroachment in the savannahs.

To benefit from its advantage when hunting, the cheetah needs the open savannah: in three seconds, it can reach a speed of 95 kilometres per hour (top left, in the Kruger National Park, South Africa). Should bushes conquer the savannah like here in Namibia (top right), Africa's meanwhile rarest big cat and many other animal and plant species will lose their habitat.

The six EMSAfrica observation stations are situated close to towns, grazing land or natural environments and are all paired: an area claimed by humans and a near-natural site as close as possible with similar climatic conditions. In the case of the Skukuza/Agincourt pair in north-east South Africa, one site is in the Kruger National Park, where human impact is minimal. The other site is near a settlement.
Photo: Visible Earth/NASA

Triple crisis for Africa's biodiversity. Press release on the study published by Martens et. al. in Conservation Biology 2022. https://tinyurl.com/2dkktaty

fixation takes place. Their advantage over C3 plants: it makes them independent of how much CO_2 diffuses passively through the stomata and they can manage well even with little CO_2 in their leaves. If extreme drought and high temperatures prevail, they keep their stomata closed to prevent water loss. And there is still sufficient CO_2 to conduct photosynthesis.

However, this more efficient CO_2 storage is now proving to be a disadvantage because the C3 trees and bushes of the savannah are benefiting more from the rising CO_2 content in the atmosphere than the C4 grasses are, with the result that the former are displacing the grass more and more. Such bush encroachment can already be observed in many places and is hardly explainable by anything other than the rise in CO_2.

Less frequent savannah fires are becoming a problem

Positive feedback could make matters much worse: this has to do with the fact that the grasses need regular savannah fires to hold their ground against trees and bushes because the

ABOUT THOMAS HICKLER

Thomas Hickler, born in 1972, worked as a postdoctoral researcher at the Department of Physical Geography and Ecosystem Science at Lund University in Sweden from 2004 to 2010, where he had also earned his doctoral degree in geobiosphere science in 2004. He has been Professor for Quantitative Biogeography at the Institute of Physical Geography of Goethe University Frankfurt and the Senckenberg – Leibniz Institution for Biodiversity and Earth System Research since 2010. Hickler is particularly interested in the interactions between biodiversity, ecosystems and climate at local and global level. His main research tools are process-based computer models for simulating biodiversity and ecosystem dynamics. He also plays an active role at the interface between science and politics, among others as author of various reports by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services and the Intergovernmental Panel on Climate Change. What he likes about the binational EMSAfrica project is how activities complement each other: "We're contributing our expertise in ecosystem modelling to the consortium and learning a lot about ecology and ecosystems in South Africa from colleagues on the ground."

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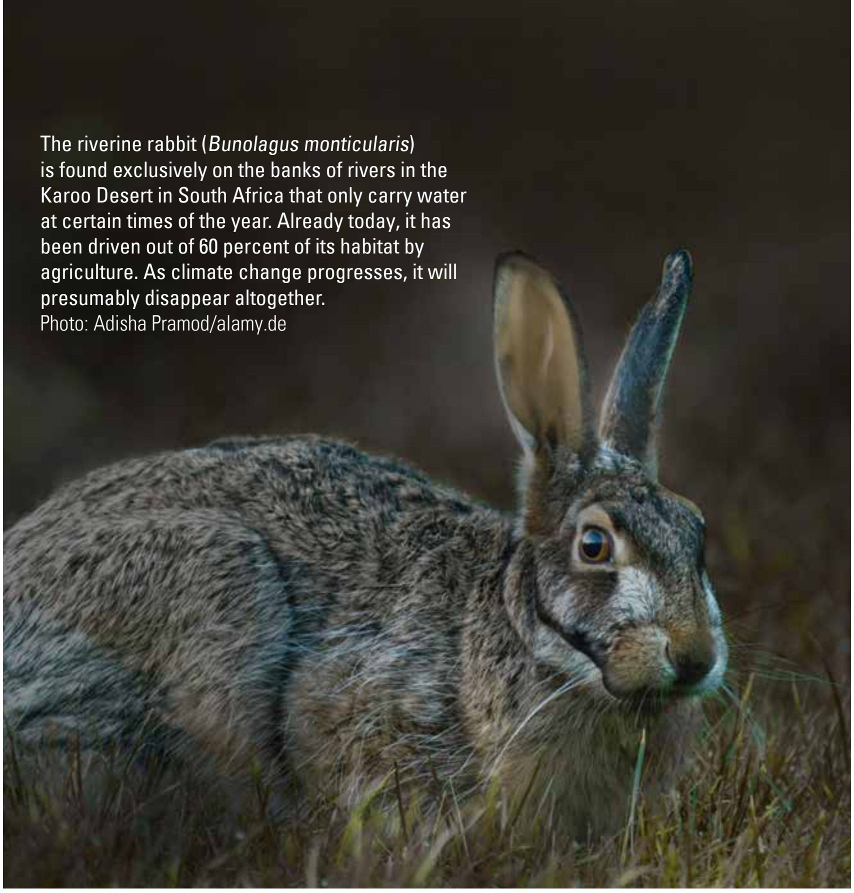

The riverine rabbit (*Bunolagus monticularis*) is found exclusively on the banks of rivers in the Karoo Desert in South Africa that only carry water at certain times of the year. Already today, it has been driven out of 60 percent of its habitat by agriculture. As climate change progresses, it will presumably disappear altogether.
Photo: Adisha Pramod/alamy.de

Reports by the IPCC (Intergovernmental Panel on Climate Change) **and the IPBES** (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services)

Ecosystem protection and climate protection must be on an equal footing, says Thomas Hickler. He meanwhile sees some progress being made here. For example, there is the Synthesis Report published in 2021 by the very well-known Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES), which is not yet quite so well-known. Hickler was a co-author. One of the report's key messages: "The ambitious implementation of land- and ocean-based actions to protect, sustainably manage and restore ecosystems have co-benefits for climate mitigation, climate adaptation and biodiversity objectives and can help to contain temperature rise within the limits envisaged by the Paris Agreement."

fires prevent too many new woody plants from growing back, which would take light away from the grasses. If bushes and trees grow faster, however, there is less grass and thus less fuel for fires. They burn less often, and as a result even more woody plants grow, casting shade over even larger areas. That is bad for the grasses and also likely to affect the fauna in the long term, says Hickler: "If the savannah becomes overgrown with bushes because of the CO_2 fertilisation effect, grass-eating grazers such as zebras and cattle will have a problem."

What adaptation strategies to halt CO_2-induced bush encroachment make sense? Hickler's preliminary answer: "Fires are already being laid today to keep savannahs and grasslands free for livestock. Such controlled fires could become even more important." In addition, human use of the savannah must be managed wisely because too much cropland and pasture also endangers natural ecosystems. "In general, we will need to be flexible and continually adapt our strategies to the latest research findings." Especially since preserving ecosystems such as the savannahs in southern Africa is not only of regional but also of global importance, namely, for climate protection: "Terrestrial ecosystems absorb about a quarter of CO_2 emissions worldwide. Global warming without this service would be far greater. We shouldn't forget that."

Guy Midgley thinks that the savannahs have a good chance of surviving climate change. "They are very resilient and adaptable. In the course of their development, they have experienced dramatic climate fluctuations and consequently exhibit considerable resilience to such changes. What's more, they are able to recover after severe droughts." However, there are also rare succulents that might react more sensitively to extreme droughts; and local endemic animals such as the riverine rabbit, some bird species, or amphibians and reptiles that could be more afflicted by climate change. ●

The author

Andreas Lorenz-Meyer, born in 1974, lives in the Palatinate and has been working as a freelance journalist for 13 years. His areas of specialisation are sustainability, the climate crisis, renewable energies and digitalisation. He publishes in daily newspapers, specialist journals, university and youth magazines.

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