TUM's activities in the **Global South**

**Three questions for Prof. Juliane Winkelmann,
Senior Vice President for International Alliances & Alumni**

Prof. Winkelmann, why does TUM engage in an array of multifaceted partnerships with institutions in the Global South?

As a leading university operating on a global scale, TUM is responsible for promoting and advancing technical progress, knowledge and entrepreneurial skills, not only here in Bavaria, but also together with our partners in the interests of spreading scientific knowledge in other parts of the world. This includes, of course, the Global South, which – depending on how you define it – is home to up to 85% of the world's population. It has become a truism that only through global cooperation will we be able to find solutions to the major challenges of our time. In our efforts to live up to our responsibilities, we want to empower and encourage talented scientific minds to create the technological and economic conditions for shared prosperity in the Global South.

Our magazine reports on research at TUM. However, TUM also participates in education and exchange programs in the Global South. What part does research play in this?

TUM is committed to the Humboldtian ideal of excellent teaching and research – and I would like to emphasize that it is difficult to conceive of excellent teaching without excellent research. In this respect, research is obviously an essential element of our cooperation with the Global South, and this issue presents a wide range of fascinating examples. What is particularly exciting about research collaborations with the Global South is that research often aims to have a direct, tangible impact. It can be very gratifying to see how solution-oriented, practical research can have an immediate impact on the ground. One example is SEED's Living Labs, which are bringing electricity to communities for the first time and studying the impact.

What can TUM researchers learn from conducting research together with colleagues from the Global South?

Research thrives on the inclusion of diverse perspectives and knowledge – and this is the absolute top priority in our cooperation activities with the Global South. In the past, however, the perspectives and knowledge of the Global South have been marginalized in scientific collaborations, and researchers have not always worked together on an equal footing. Today, we have moved on: we understand that we can – and must – learn a great deal from our colleagues and communities in the Global South, from local sociocultural and economic conditions to natural circumstances, the relevance of different issues and what data we should collect, where and how. It is only together that we can explore complex issues, so everyone has a lot to contribute. ■

What exactly is the Global South?

The term Global South is used to describe the situation of countries in our globalized world in the most neutral, non-hierarchical way possible. Countries considered part of the Global South are politically, economically or socially deprived states. By contrast, countries in the Global North are described as having a position of privilege in terms of their prosperity, political freedom and economic development. These terms only correspond to geographical location to a limited extent. For example, Australia and New Zealand and considered part of the Global North, while countries like Afghanistan and Mongolia are assigned to the Global South.

A Parasite with
Side Effects

Pork tapeworm infection is one of the major causes of epilepsy, which affects around 50 million people worldwide, mostly in the Global South. The condition is curable with the right treatment. Even better, however, is awareness raising and disease prevention as part of the One Health concept.

Tanzania

Gesamter Artikel (PDF, DE): www.tum.de/faszination-forschung-30
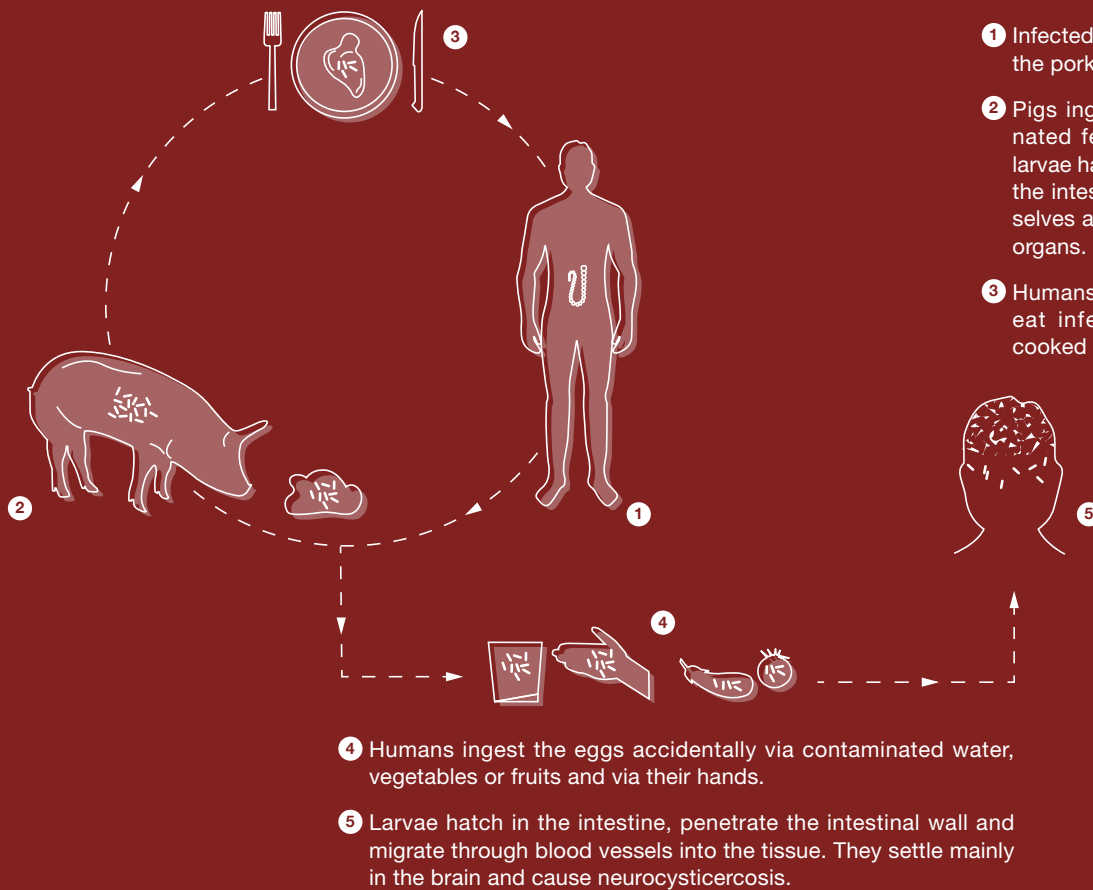
Ein Parasit mit Nebenwirkungen D

Neurologische Krankheiten haben weltweit die höchste Krankheitslast und die zweithöchste Mortalität. Prof. Andrea Winkler erforscht den Zusammenhang zwischen Epilepsie und Neurozystizerkose – einer Infektion mit Larven des Schweinebandwurms *(Taenia solium)* im Gehirn. Ihr Fokus liegt jedoch nicht nur auf neuen Diagnose- und Therapieoptionen, sondern auch auf verbesserter Prävention im Sinne eines One Health-Ansatzes. □

Link

www.med.tum.de/en/center-global-health-0

www.neurologie.mri.tum.de/de/arbeitsgruppen/globale-neurologie-neuroinfektiologie

1. Infected humans excrete the eggs of the pork tapeworm.

2. Pigs ingest the eggs with contaminated feces. In the pig's intestine, larvae hatch from the eggs, penetrate the intestinal wall and deposit themselves as cysts in muscles and other organs.

3. Humans ingest the cysts when they eat infected raw or insufficiently cooked pork.

4. Humans ingest the eggs accidentally via contaminated water, vegetables or fruits and via their hands.

5. Larvae hatch in the intestine, penetrate the intestinal wall and migrate through blood vessels into the tissue. They settle mainly in the brain and cause neurocysticercosis.

Neurocysticercosis: a major cause of epilepsy. The life cycle of the pork tapeworm *(Taenia solium)* includes humans as main hosts and pigs as intermediary hosts; through lack of hygiene and sanitation humans can become accidental intermediary hosts and develop neurocysticercosis.

In 2002, Andrea Sylvia Winkler traveled to Tanzania. While others went on a photo safari in the savannah, the young doctor wanted to help local people suffering from epilepsy. She soon noticed that very little was known about the condition and its specific local causes. Even today, more than 20 years later, the expert in global neurology at TUM is not letting go of the topic. "A large number of patients have hope of a cure," explains Winkler. Neurological disorders like epilepsy, stroke and dementia account for the world's largest burden of disease, have the second highest mortality rate, and increasingly affect the Global South. However, especially in low-income countries, these conditions often have different causes, resulting in a need for specific research.

Unlike in Germany, for instance, around one third of all epilepsy cases in Tanzania are caused by an infection with *Taenia solium*, commonly known as pork tapeworm. This parasite lives primarily as a larva in the muscle tissue of pigs and as an adult tapeworm in the intestines of humans. However, people can ingest the eggs of this tapeworm through contaminated water and food, and also through poor hygiene. The eggs hatch into larvae, each about half a centimeter to a centimeter in size, which can penetrate the intestinal wall and migrate to muscles, skin or especially the brain.

The larvae encapsulate themselves and are therefore not recognized by the immune system. Many patients remain asymptomatic for years, and have no idea that they are carrying a ticking time bomb. It is only when a trigger – which remains unknown – causes the immune system to attack the encapsulated larvae that an inflammatory response occurs, which can lead to neurological signs or symptoms including severe headaches, paralysis, a loss of intellectual capacity or even epilepsy. The medical term for this infection is neurocysticercosis (NCC).

A neglected tropical disease

The pork tapeworm does not only occur in Tanzania; other countries in sub-Saharan Africa, Latin America or Southeast Asia are also affected. Nevertheless, **NCC**[1] is one of the neglected tropical diseases. There has been little research in this area so far. Funding? Not a chance. In the beginning, Andrea Winkler has to convince donors that it is worthwhile to invest in research on the prevention and treatment of such poverty-related diseases. Her demand is clear: "We Europeans must take the issue seriously! We have a moral and social obligation to do so and we will see more and more NCC cases also in Europe due to migration. Moreover, research on NCC generates valuable knowledge that can be transferred to other neurological diseases."

Since 2016, there has been genuine, major progress on the issue. Through funding from the German Federal Ministry for Education and Research (BMBF) and the EU, the SOLID and CYSTINET-Africa cooperation projects were launched. Andrea Winkler, who is now a Consultant Neurologist at TUM and Professor of Global One Health at the University of Oslo, is Co-Director of CYSTINET-Africa. Also on board is her colleague Prof. Clarissa Prazeres da

[1] Neurocysticercosis (NCC)
is an infection with larvae of the pork tapeworm within the brain, which can cause neurological disorders such as epilepsy.

Costa from TUM, along with four research institutes and universities from Tanzania, Zambia and Mozambique. Together they want to find out how to better diagnose and treat NCC. At the same time, educational initiatives in local communities serve to raise awareness of the disease. One problem so far has been that NCC can only be diagnosed beyond doubt with neuroimaging such as CT or MRI. But the necessary equipment is expensive and rarely found in Africa. Within the framework of SOLID, an inexpensive and easy-to-use blood test was developed that provides very good indications of whether someone is infected with the pork tapeworm or not. Only those who receive such a positive blood test should subsequently be examined further. The test has already been explored in hospitals and under field conditions. The results have recently been published in *The Lancet Infectious Diseases.*   ▷

Picture credit: private collection; Graphics: ediundsepp (source: TUM)

During her stay in Tanzania, Andrea Winkler examines a child for possible neurological disorders.

Interdisciplinary research for better results

The special feature of both projects is their interdisciplinarity. "We don't just see the problem as strictly medical," says Andrea Winkler. A medical doctor herself, she knows the boundaries of her field only too well. Would it be possible to offer the millions of people who suffer from NCC adequate treatment with expensive medications and complex surgeries? Unfortunately not. But could new infections be prevented or at least reduced? Now, that's feasible.

With this in mind, Winkler takes a step back – to a point in time before an individual even requires treatment. That is why veterinarians and social scientists are part of the project team. Working together, these experts discuss where the problems lie and where improvement is needed. Together with political representatives and other decision-makers, they develop policies that are later adopted by local and global decision-making bodies such as the World Health Organization (WHO). "Our focus is not only on treatment but also on prevention, because, although treatment is possible, it is expensive," explains Winkler.

"We Europeans must take poverty-related diseases seriously. We have a moral and social obligation to do so and we will see more and more NCC cases also in Europe due to migration."

Andrea Sylvia Winkler

Experts travel to the villages and talk to local people about the spread of the parasite and how to contain it. This includes not eating raw pork, treating sick animals with low-cost deworming medication and keeping animals in pens rather than allowing them to roam freely through the villages where they could become infected by ingesting the feces of people carrying the tapeworm. The overarching concept behind these efforts is the Global One Health approach, in which human health is only possible when animals and the environment are also healthy.

To get closer to this goal, Andrea Winkler founded the Center for Global Health at TUM in 2017 together with Clarissa Prazeres da Costa, supported by the Department of Neurology and the Institute of Medical Microbiology, Immunology and Hygiene. The CGH aims to initiate research and teaching projects on the topic of global health, bringing together specialists from various disciplines: "We're moving beyond the national framework and collaborating worldwide." ◼ *Claudia Doyle*

Prof. Andrea Sylvia Winkler

studied medicine at LMU Munich, where she also completed a doctorate in neuroscience. She received a second doctorate in clinical neurology from the University of London. She became a Consultant Neurologist at TUM in 2011 and, later, a co-founding Director of the TUM Center for Global Health together with Prof. Prazeres da Costa. Winkler accepted a professorship in Global One Health at the University of Oslo in 2016. In May 2023, she started a visiting professorship at Harvard Medical School. One focus of her work is research into neglected neurological diseases in sub-Saharan Africa together with the One Health concept.

Affordable Electricity for **Remote Rural Communities**

What happens when a village gains access to solar power? Prof. Frank-Martin Belz and his team work in rural regions of developing countries to examine which entrepreneurial activities unfold with the benefit of electricity.

Link

www.ie.mgt.tum.de/en/sustainability
www.seed.tum.de

Mali
Kenya
Uganda

Bezahlbarer Strom für entlegene Dorfgemeinschaften

D

Prof. Frank-Martin Belz baut in ländlichen Regionen von Entwicklungsländern Reallabore auf und untersucht, welche unternehmerischen Aktivitäten sich entfalten, wenn eine Energieversorgung vorhanden ist. Seine ehemalige Doktorandin Esther Salvi erforscht die Schattenwirtschaft in solchen ländlichen Regionen. Der Sektor wird vom Staat weder reguliert noch besteuert oder beaufsichtigt und ist von mündlichen Absprachen, Traditionen oder Riten geprägt. □

Graphics: ediundsepp

Prof. Frank-Martin Belz

studied business administration at the University of Mannheim, before receiving his doctorate and qualifying as a professor at the University of St. Gallen (Switzerland). He is a Professor of Corporate Sustainability at the TUM School of Management and Director of the TUM SEED (Sustainable Energies, Entrepreneurship and Development) Center, which pursues an international and interdisciplinary approach.

"**A**round 700 million people around the world have no access of any kind to electricity. The majority live in sub-Saharan Africa – in locations far from national electricity grids. In such cases, mini-grids consisting of photovoltaic systems and batteries can provide a reliable supply of affordable electricity for entire villages," explains Frank-Martin Belz, Professor of Corporate Sustainability at TUM.

Rural communities can use these mini-grids to turn their mills, operate water pumps to irrigate their fields, and thereby advance the local economy. In most cases, these local economies are made up of small, family-run agricultural businesses. However, with a secure electricity supply at their disposal, local people could run an Internet kiosk, a TV bar or a clothing repair service.

In the past, Belz has examined the sustainability activities undertaken by large corporations in industrial nations. He was struck by the lack of willingness to embrace change. Belz, who is a keen triathlete, was determined to make a difference – so he changed himself. He reoriented his research, focusing on entrepreneurs "who pursue social and ecological goals, developing entrepreneurial solutions for sustainability-related problems".

"As I move into the last ten years of my career," the 57-year-old researcher explains, "I am investigating the relationship between sustainable energy systems and entrepreneurship in the Global South. In addition to academic publications, I also want to create living labs by setting up mini-grids in rural areas and giving people access to electricity from renewable sources."

"I want to create living labs by setting up mini-grids in rural areas and giving people access to electricity from renewable sources."

Frank-Martin Belz

One such living lab has been set up in Kyampisi, Uganda, where researchers and project partners established an electricity grid, including storage, powered by 28 solar panels. The TUM research team is now analyzing the economic activities that develop when a local grid provides a secure electricity supply. In the past, papayas and mangoes had been left in the field to rot. Giving farmers access to power empowers them. It gives them the ability to cool and process their fruits. This allows them to grow commercially and increase their quality of life. ▷

From experience gained in a previous mini-grid project in Kenya, the researchers know that local electricity grid operators cannot rely on private customers alone in their efforts to turn a profit. Instead, they also need a certain number of small-scale entrepreneurs to purchase electricity. At present, the project participants are working with micro-businesses in Kyampisi to create a suitable business model capable of driving sustainable development. A second factor relates to social aspects: once people achieve commercial success, they find themselves with a financial obligation to their extended family. It is therefore important to research the paths that new entrepreneurs forge, how their family situations change and what opportunities are open to women. Another area of research focuses on the informal economy, which Belz and his team has investigated in Mali.

To Belz, the current situation in rural regions of Africa is reminiscent of Germany in the early 1900s, with the establishment of energy supplies laying the foundations for economic success. By 2030, the Konstanz-born researcher aims to implement the infrastructure required to electrify eight villages in various African countries, thereby aiding and supporting the development of around 8,000 people. ■ *Eve Tsakiridou*

Informal Economies:
The West Needs to Abandon its Misconceptions

As a PhD student at the Chair of Corporate Sustainability, Dr. Esther Salvi conducted field studies in rural Mali to find out how informal economies work. The sector follows uncodified rules such as oral agreements, traditions and rites. It is the part of the economy that is neither registered, taxed nor monitored by the state.

Dr. Salvi, how did you arrive at your field of research?
I spent several weeks in five rural villages in Mali, conducting interviews with shop owners, farmers, agriculturists, welders, hairdressers, village chiefs, women leaders and religious leaders. The more I talked to these entrepreneurs, the more I understood the key role they play within their society and for local development. I noticed that they do not fit into any "classical" entrepreneurship box. I realized how important it is to understand their culture, the unwritten rules guiding their behavior and economic activities.

So how is your field of research different from others?
In its interdisciplinarity and the need to abandon our Western misconceptions. To truly understand how rural informal entrepreneurs operate their ventures in some of the most fragile settings in the world – with absent or ineffective state authorities – and how they create value for their society, you also need to take a sociological and anthropological perspective. ▷

What are the most important findings of your project?

Informal entrepreneurs in rural Mali are facing formal fragility due to the lack of effectiveness of the national government, which is too far from the local villages to truly understand their needs, intervene in local dynamics, and provide functioning services and infrastructure. However, the rural villages are characterized by a high level of stability in terms of informal institutions, which guide entrepreneurial activities. These informal institutions differ across villages and are constituted by large family rules, community practices and ethnic traditions.

For example, in agricultural villages you are not allowed to start an enterprise if you do not harvest your family field beforehand, or if you do not provide for the livelihood of your large family, which generally includes a husband and wife, plus the husband's parents, husband's brothers and unmarried sisters, children, husband's grandparents and so on. You also need to make sure that the chief of the village gives you permission to start your business in the village.

What impressed you the most?

I was most impressed by how rich the rural villages are. We usually see them as settings that are "lacking": they lack infrastructure, they lack reliable access to electricity, they lack enforcement of formal rules, etc. However, they are extremely rich in terms of cultural practices, traditions and social values. Rural villagers, including informal entrepreneurs, truly care for each other, understand each other and support each other through reciprocity and solidarity practices. They tend to engage in their daily activities prioritizing collective rather than individual needs. Entrepreneurs in rural Mali thus show us examples of alternative business models beyond the capitalist one.

Besides this, what can we do with the knowledge of informal economies?

Basically, you cannot succeed as an entrepreneur in rural Mali if you do not understand these dynamics, nor can you succeed as an NGO or social enterprise willing to work in this setting if you do not understand the informal rules. ■   *Eve Tsakiridou*

Dr. Esther Salvi

obtained her PhD at TUM School of Management, where she graduated with highest distinction in May 2023. In her dissertation she developed a theoretical basis for informal economies. During that time, she served as research assistant at the Chair of Corporate Sustainability at TUM and as research coordinator of the TUM SEED Center. In her Bachelor's degree, Esther Salvi studied food technology (University of Turin) and she holds a Master's degree in Nutritional Sciences (University of Milan). In May 2023, she started a postdoc position at LMU School of Management in Munich.

Resolving Conflicts Between **Artificial Intelligence and Ethics**

While AI harbors tremendous potential for African countries, its use can sometimes present different ethical and social challenges than in more industrial nations. A team at the Institute of Ethics in Artificial Intelligence has co-founded a platform that brings African AI experts together – and promotes ethical, sustainable AI development.

Link
www.gov.sot.tum.de/en/wirtschaftsethik www.ieai.sot.tum.de www.rainafrica.org

Ghana

Künstliche Intelligenz und Ethik zusammenbringen

D

Künstliche Intelligenz kann afrikanische Länder entscheidend voranbringen, zum Beispiel in der Landwirtschaft, im Gesundheitswesen oder in der Stadt-planung. Auch die TUM ist über ihr Partnernetzwerk in Afrika an vielen KI-Projekten beteiligt. Dort spielen nachhaltige und ethische Aspekte in der KI-Entwicklung eine viel stärkere Rolle als in Europa oder den USA. Ein Team des TUM Institute of Ethics in Artificial Intelligence (IEAI) hat eine Plattform mitgegründet, die afrikanische KI-Experten vernetzt und eine ethische und nachhaltige KI-Entwicklung fördert. □

Graphics: edundsepp

When we think about Africa, artificial intelligence is unlikely to be the first thing to spring to mind. And yet, AI is a topic of huge importance on the African continent. One reason is that the technology does not require heavy industrial infrastructure or conventional factories and is not necessarily capital-intensive to develop.

A more important factor, however, is that AI enables African countries to take steps forward in their development that that would otherwise not be possible. Take agriculture, for example – a crucial sector for the continent – where AI can help farmers to optimize fertilization and irrigation processes. In urban development, AI-based Earth observation systems can identify and support the planning for informal settlements (commonly known as slums). And, in the healthcare sector, AI can help to improve the medical situation for rural populations.

Many African researchers and scientists are cooperating with European institutions. TUM is no exception, having established an extensive partner network in Africa and participating in many AI-related and other projects. Through this work, it has become apparent that, in addition to technological issues, aspects surrounding sustainability and ethics have an important role to play in Africa – possibly far more so than in Europe or the USA.

"Responsible AI" is a high priority in African countries, and with good reason. For instance, while facilitating the AI-based monitoring of informal settlements may appear a purely technical problem at first glance, the ethical implications can make the entire project appear dubious. If excavators move in on the basis of such data because the government wants to hide the existence of such settlements from the public, the consequences could be grave. The residents would be evicted and forced to find a new place to live.

Prof. Christoph Lütge can recount a series of stories of similarly problematic ethical consequences of AI development projects. Director of the Institute of Ethics in Artificial Intelligence (IEAI) at TUM and co-founder of the Responsible AI Network in Africa, Lütge is convinced that AI will inherently fail to function without ethical considerations – and that such aspects should be taken into consideration when developing AI applications. "We're frequently confronted with similar ethical problems with AI, all around the world," explains Lütge. "So, it's important we tackle these problems not only by working at the local level but also through networking."

Members of TUM IEAI participate in a conference on "Responsible AI and Ethics – A Panacea to Digital Transformation in Sub-Saharan Africa" at KNUST, Ghana. RAIN-Africa co-hosted this event with the KNUST Responsible AI Lab.

Professor Mrs. Rita Akosua Dickson, Vice-Chancellor, KNUST speaking at the Responsible AI and Ethics Conference in Kumasi, Ghana.

Connecting African AI experts

In recent years, the IEAI has established several networks to promote the discussion of ethical challenges related to AI use and prevent social dislocation. One such network, the Responsible AI Network Africa (RAIN-Africa), focuses specifically on African countries. It was founded in 2020 through a partnership between the IEAI and the Faculty of Electrical and Computer Engineering at the Kwame Nkrumah University of Science and Technology in Ghana (KNUST) in Ghana. In addition to Lütge, the other co-founders of RAIN are his colleague Dr. Caitlin Corrigan, TUM doctoral student Laud Ammah, and Prof. Jerry Kponyo from KNUST.

"In RAIN-Africa, we are bringing African AI experts together," explains Caitlin Corrigan, Executive Director at the IEAI. "The platform enables users to jointly discuss and develop projects related to the ethical and social challenges at the interface of technology and human values – and especially with regard to sustainable development."

Specifically, Corrigan organizes events, online workshops and live conferences on the platform – supported by her colleagues at TUM in Munich and at KNUST in Ghana. "This gives scientists and AI experts a platform for exchanging ideas – about ongoing projects and how they're implementing them. They can also find research partners in their fields of work," says Corrigan. The RAIN-Africa project hopes to stimulate international and interdisciplinary cooperation through a series of virtual and in-person workshops.

Putting community benefits first

Fairness is a perennial ethical challenge at the conferences and workshops hosted by the RAIN-Africa platform. "For many people, the central question is whether the benefits of this technology are distributed fairly, justly, or whether only a select few stand to profit," explains Corrigan. "This aspect is decidedly crucial in Africa."

People in the south of the continent in particular draw on a special ethical approach: Ubuntu ethics. Unlike Western ethical concepts, which often have an individualistic focus – such as Kantianism, utilitarianism and virtue ethics – Ubuntu ethics considers the individual as inextricably linked with others and prioritizes the community above the individual. Given the inherent links between the well-being of the individual and their society, the rights of the individual are subordinate to the benefits to society.

This ethical concept has very tangible impacts: "If a community can use a healthcare app, the individual should be willing to disclose their data," says Corrigan. "Data protection is sometimes sacrificed in a Covid tracing app, for instance – but, in return, that app can protect the whole community." As Corrigan explains, this issue has been raised time and again at recent RAIN-Africa conferences – though it has also been the subject of considerable discussion in other countries in the context of the Covid-19 pandemic.   ▷
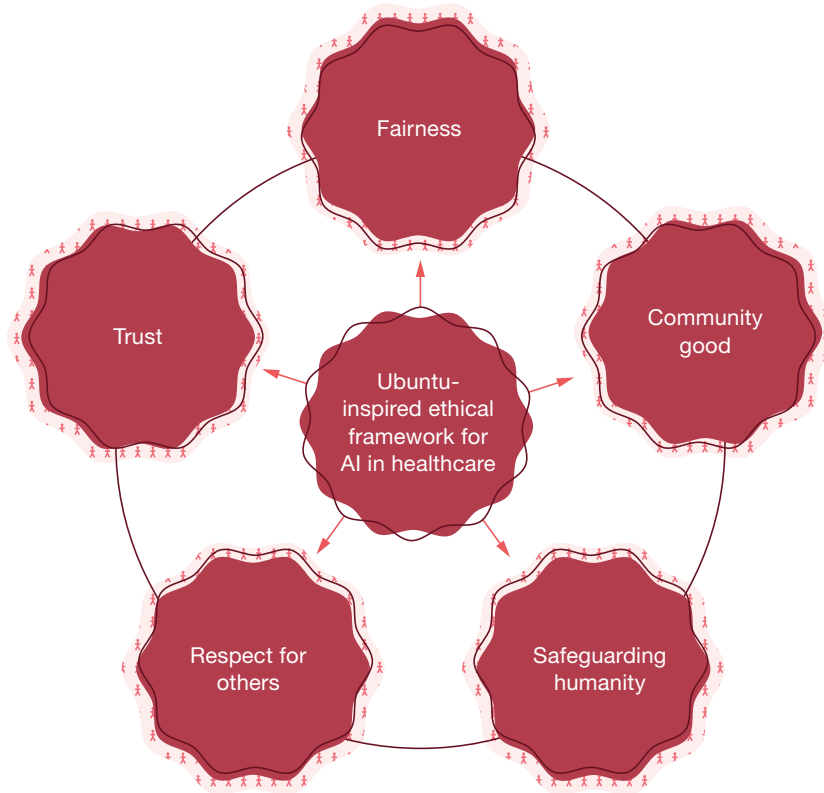
Ubuntu ethics, which emphasizes the interconnectedness and interdependence of all people, provides a promising framework for addressing ethical concerns in AI for healthcare. Researchers at the IEAI, along with partners in Namibia, developed the framework above.

In some cases, speed is also given priority over individual data protection – especially in critical situations. "A discussion point at the latest RAIN-Africa conference was about the 'responsibility' of launching an AI-enabled app in society as quickly as possible, even if it isn't perfect," says Corrigan. Developers from African countries want to help people who might live too far from a hospital or don't have a doctor nearby. It can therefore be important to deploy such apps as quickly as possible and then iteratively refine them. "Socially beneficial applications like this are often associated with the question of how we define 'responsible' and how different ethical concerns could come into conflict. For example, should data processing regulations be given priority over promoting access to healthcare?"

These examples are just a fraction of the entire range of AI-related ethical problems that are discussed in the RAIN-Africa Network with the aim of creating solutions to a variety of challenges related to sustainable development. In all probability, such networks could also yield benefits in other regions, given their potential to bring discussions of AI and ethics together worldwide. ∎
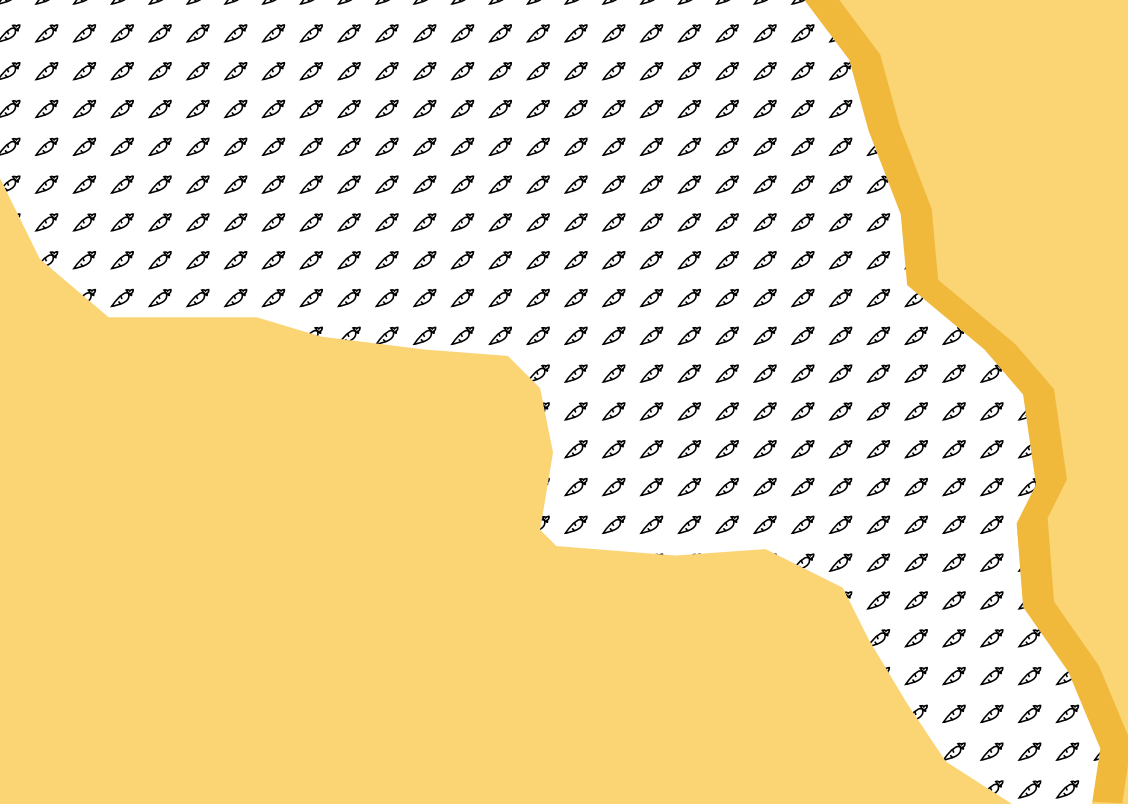
Klaus Manhart

Prof. Christoph Lütge

has held the Chair of Business Ethics at TUM since 2010 and has been active as Director of the Institute for Ethics in AI (IEAI) since 2019. He studied business informatics and philosophy, completed his doctorate at TU Braunschweig and earned his habilitation at LMU Munich. Lütge was awarded a Heisenberg Fellowship in 2007 and appointed a Distinguished Visiting Professor by the University of Tokyo in 2020 and has been a guest lecturer at Harvard, Pittsburgh, Taipei, Kyoto and Venice. Moreover, he is a member of the Scientific Committee of the European AI ethics initiative AI4People, and of the German government's Ethics Commission on Automated and Connected Driving. Lütge has been actively engaged in projects in Africa for some time. In March 2023, he traveled extensively in sub-Saharan Africa and visited universities associated with RAIN-Africa in South Africa, Namibia, Cape Verde and Senegal.

Dr. Caitlin Corrigan

has been engaging with issues surrounding sustainable development in Africa for over ten years. She received her doctorate in Public and International Affairs from the University of Pittsburgh. For her doctoral thesis, she focused on the governance of natural resources, specifically in sub-Saharan Africa, including conducting field research in Botswana and South Africa. She was also the Program Development Manager, developing research projects and grant applications, for the University of Pittsburgh's Africa Studies Program. As Executive Director of the IEAI at TUM, Caitlin Corrigan is responsible for developing and coordinating all its research and administrative activities. She also works closely with the institute's director to shape its agenda.

A Long-Term
Ménage à Trois

Connecting water, energy and food to save the world – that's the mission undertaken by an international research initiative focusing on the Water-Energy-Food (WEF) Nexus. Its researchers are developing alternative solutions to the consumption of natural resources in large and small cities and their surroundings around the world.

Leh, India

South Africa
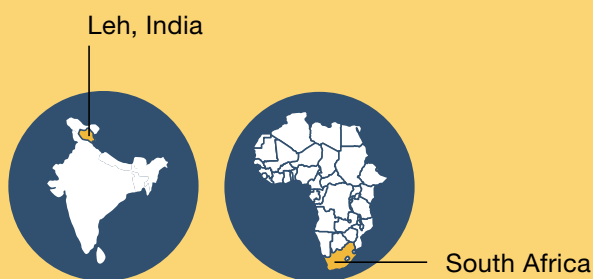
*Gesamter Artikel (PDF, DE): www.tum.de/faszination-forschung-30*

Langfristige Ménage-à-trois   D

Wasser, Energie und Nahrung: An alternativen Lösungen für den Verbrauch dieser Ressourcen in großen und kleinen Städten forschen Prof. Jörg Drewes und Dr. Daphne Keilmann-Gondhalekar. Etwa für die kleine Stadt Leh im indischen Himalaya, die an Wassermangel leidet. Hier entwickeln sie ein dezentrales System zur Wasserwiederverwendung, das die Stadt unabhängiger von externen und weit entfernten Wasserquellen machen könnte. □

Centralized sewage system

Storage

Pumping

Indus
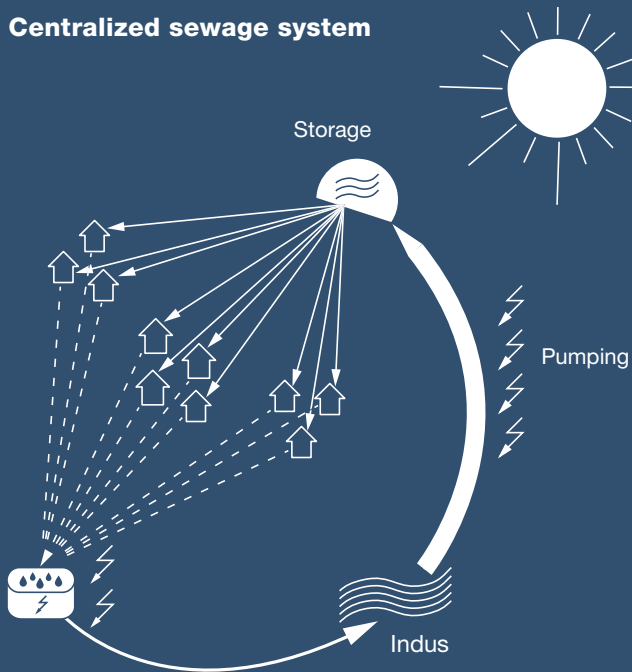
Alternative, decentralized system

Storage

Pumping

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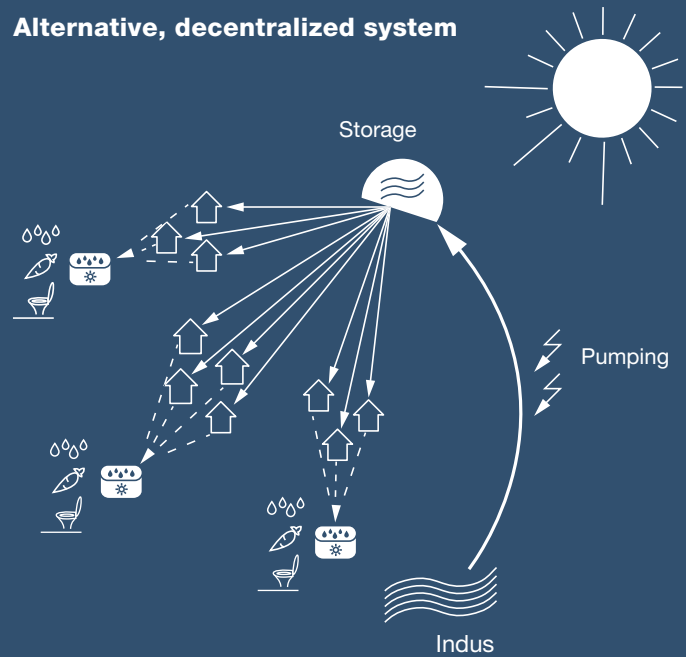
Sewage treatment plant – powered by conventional electricity

Sewage treatment plant – powered by solar energy

A concept for a decentralized wastewater system developed with the residents of the city of Leh. The water is reused locally, such as to cultivate vegetables or flush toilets. This type of system would reduce demand for fresh water, cut the waste stream, save energy and help to grow food locally.

A morning shower followed by brushing your teeth, turning on the radio and making a coffee. Sound familiar? This morning routine, which many of us take for granted, is actually a significant organizational effort – especially in major cities. Particular complications include the rising demand for natural resources like water, energy and food, which is caused in part by a further complication: the consequences of climate change. In Los Angeles, for example, high temperatures drive up energy consumption due to increased use of air-conditioning systems in buildings. Glacial melting in the Swiss Alps is reducing water supplies, meaning that water has to be sourced from elsewhere. These are just two of many examples of the impacts of climate change. Against this backdrop, it is essential that we bring our consumption of resources down to a sustainable level.

But how can we achieve this? While this ultimately means consuming less, we can also promote integrated planning of three closely connected sectors: water, energy and food. Agriculture and energy production facilities both require water. Transporting water and food also requires energy. Integrating plans for supplying these resources

can generate synergies. Or, to put it differently: if water, energy and food were engaged in a ménage à trois, they would be equal partners who support and rely on each other – and communicate effectively to maintain a functioning and optimal relationship.

However, consideration of the interrelationships between these resources has barely penetrated teaching and research, and practice even less so. "We need a circular perspective rather than a linear one," underscores Prof. Jörg Drewes, who heads the Chair of Urban Water Systems Engineering at TUM. Since 2017, the Chair has been home to the Urban Water-Energy-Food Nexus research group, led by Dr. Daphne Keilmann-Gondhalekar. Together, they initiated the Nexus@TUM research and teaching agenda in 2021.

> *"We need a circular perspective on water, energy and food rather than a linear one."*
>
> Jörg E. Drewes

Graphics: ediundsepp (source: TUM)

Using a small city in the Himalayas as a model for sustainable resource management

Drewes, Keilmann-Gondhalekar and their team have already completed several pilot projects, including in India and Niger, but also in Bavaria. Their interest is in regions where natural resources are scarce and there is a need for novel solutions usually not yet financed by the public purse. One example is Leh, a city in the Indian Himalayas, surrounded by desert. Over recent decades, the city has experienced exponential growth, driven by tourism, and is now grappling with limited water resources. Drewes, Keilmann-Gondhalekar and their team have been working in the area for over a decade. Conventional concepts developed and financed externally – such as a time-consuming, expensive plan to install a pipeline to pump water to Leh – have not yet yielded the desired results. The Nexus researchers have recorded and measured demand for water and spoken with many local residents. They agree that, rather than transporting water to the city from elsewhere, a better option would be to capture, treat and reuse the wastewater generated in Leh. Every hotel, guesthouse and household could feed their used water into a decentralized system so that it could be used, for example, to irrigate fields and serve as fertilizer. This type of system would reduce demand for fresh water, cut the waste stream, save energy and help to grow food locally. It would also give the city greater independence than having to rely on (and pay for) water to be transported from elsewhere. "This example shows the need for new concepts that are developed, implemented and financed together with local people," comments Dr. Keilmann-Gondhalekar.

Leh has also afforded Keilmann-Gondhalekar another vital insight: "We need new computational models to calculate potential demand," she says. "The most affordable solution in the short term is usually not the most affordable in the long term." For instance, it may cost more to build a decentralized water system than a centralized one. Conventional calculation methods, however, usually fail to take into account the sharply rising value of water. Consequently, the researchers have turned to multi-criteria decision-making analysis. This is a decision-making method that affords equal weight to various criteria that are not easy to compare or quantify. ▷

"The Indian city of Leh is an example showing the need for new concepts that are developed, implemented and financed together with local people."

Daphne Keilmann-Gondhalekar

Time to turn words into action

In South Africa, Drewes' team is currently developing concepts for informal settlements – more commonly known as slums. In these areas, electricity, water and adequate sanitary facilities are all in short supply, with local people unable to establish farming fields and produce food. Streams and rivers are contaminated with waste, which leads to health problems. These problems are linked and can exacerbate each other in a downward spiral.

In this project, like in their other research, the scientists gather information and record demand for water, energy and food, while students write papers on potential solutions – such as using renewable energy sources like wind, solar and biomass, producing biogas from waste, and capturing rainwater. "The latter is something we don't even do in a modern city like Munich," says Drewes. "There are plenty of ideas and we already have some solutions but, unfortunately, we aren't implementing them." Keilmann-Gondhalekar adds: "We urgently need to act." This is why Nexus@TUM goes far beyond examining technical aspects. It aims to motivate people, create acceptance, highlight transformation pathways, win the support of various stakeholders (including governments), teach environmental engineers the importance of Nexus approaches – and much more besides. Consequently, Nexus@TUM also relies on input from researchers in the social and political sciences. "Our research is made meaningful by adopting an interdisciplinary approach. Implementation will only succeed if we work together with local people in a long-term, transdisciplinary approach that is built on trust," says Drewes. ∎ *Gitta Rohling*

Get involved!
Nexus@TUM welcomes researchers from all disciplines. For more information, visit: www.nexus.wasser.tum.de

Prof. Jörg E. Drewes

has led the Chair of Urban Water Systems Engineering at TUM, along with the associated research center, since 2013. Before taking up his position at TUM, he was a Full Professor at the Colorado School of Mines, USA and Director of Research at the NSF Engineering Research Center on Reinventing the Nation's Urban Water Infrastructure. He is a member of the German Advisory Council on Global Change (WBGU) and Co-Chair of the Drinking Water Commission at the German Federal Ministry of Health.

Dr. Daphne Keilmann-Gondhalekar

is an urban planner and leader of the Nexus research group at the Chair of Urban Water Systems Engineering at TUM, concentrating on integrated urban planning, the urban Water-Energy-Food Nexus and multi-stakeholder processes. She received her doctorate from the University of Tokyo and was a Postdoctoral Associate at the Massachusetts Institute of Technology (MIT).

How Much CO$_2$ Can Forests Absorb in the Future?

Amazonia

Tropical rainforests absorb huge amounts of carbon dioxide. But how are increasing levels of this greenhouse gas likely to affect the forests' future growth? A large outdoor experiment in Amazonia aims to cast light on this issue by subjecting sections of the forest to elevated carbon dioxide levels. Ecosystem modeler Prof. Anja Rammig is part of the research effort.
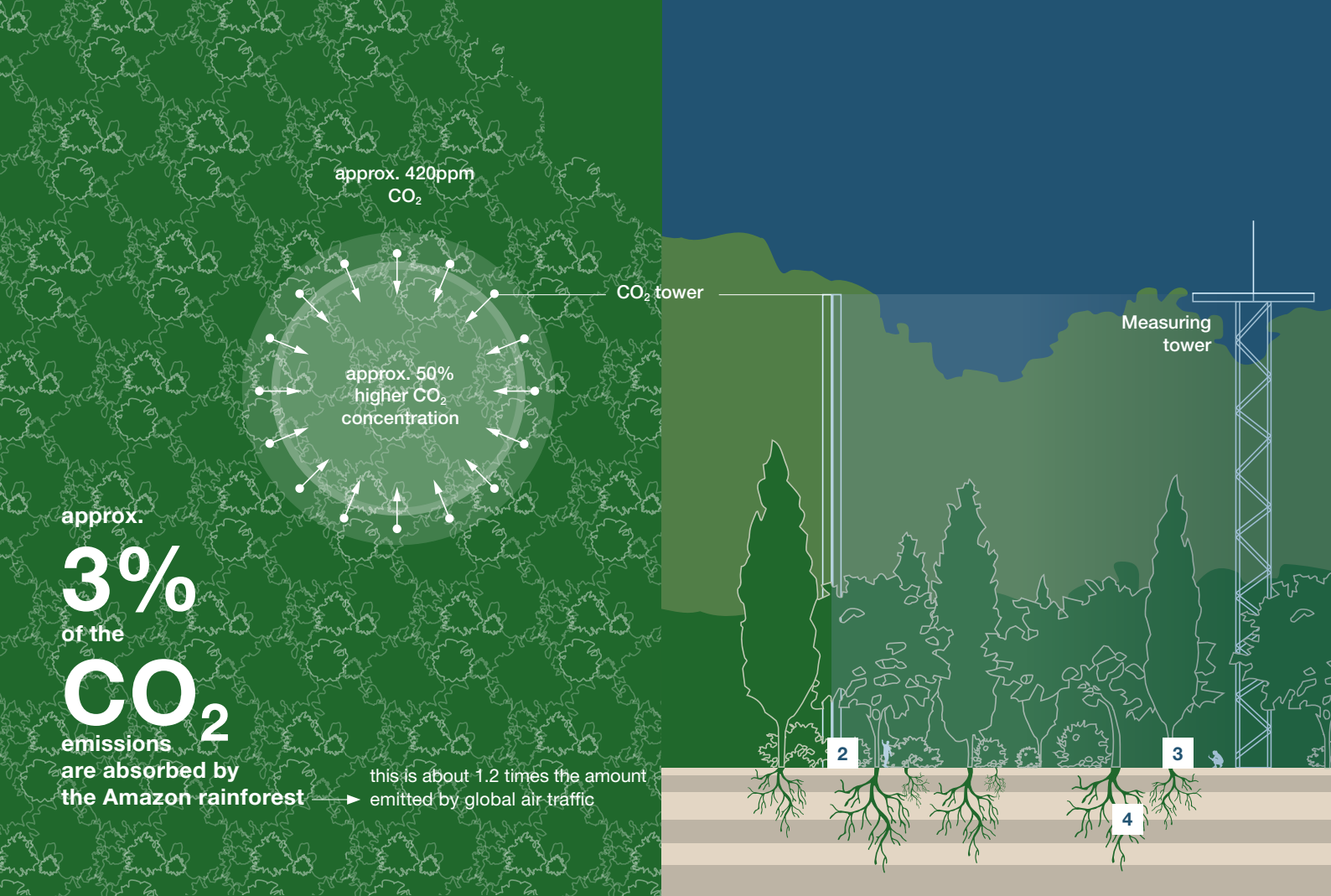
Link

www.lsai.wzw.tum.de/en/home
www.amazonface.unicamp.br/en/

Wieviel CO$_2$ können Wälder künftig noch aufnehmen? D

Der Amazonas spielt eine wichtige Rolle im Klimasystem der Erde. Er nimmt einen großen Teil des Klimagases Kohlendioxid (CO$_2$) auf und bremst so die Erderwärmung. Wieviel CO$_2$ der Amazonas in Zukunft speichern kann, ist ein wichtiger Parameter für globale Klimamodelle, aber bisher noch weitgehend ungeklärt. Klimamodelle nehmen vereinfachend an, dass der Wald umso stärker wächst, je mehr CO$_2$ er aufnimmt. Ob das tatsächlich stimmt oder ob beispielsweise die Nährstoffversorgung ab einem bestimmten Punkt das Wachstum hemmt, klärt nun ein internationales Experiment, das ein definiertes Gebiet im Amazonas mit CO$_2$ begast. Mit dabei ist die Ökosystemmodelliererin Prof. Anja Rammig. □

approx. 420ppm
CO_2

approx. 50% higher CO_2 concentration

CO_2 tower

Measuring tower

approx.

3%

of the

CO₂

emissions
are absorbed by
the Amazon rainforest ➡ this is about 1.2 times the amount
emitted by global air traffic
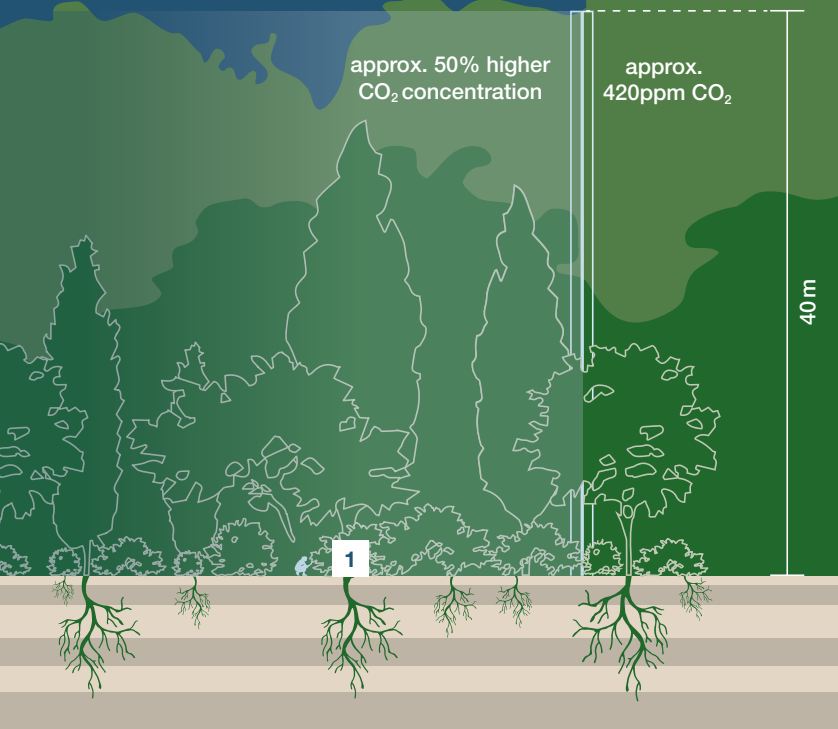
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3

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The Amazon rainforest is vast; a seemingly endless green carpet, sprawling over an area around 14 times the size of Germany. In addition to serving as a habitat for plants and animals, the rainforest plays a vital role in regulating the Earth's climate. This involves absorbing a large amount of the carbon dioxide (CO_2) released by humans burning oil, gas and coal. Without the Amazon, climate change would progress even faster. However, exactly how much carbon dioxide the Amazon rainforest will be able to store in the future remains largely unknown because, until now, there has been no field experiment investigating how this huge ecosystem processes the greenhouse gas.

A forest of gas-emitting towers

To date, climate models have relied on the assumption that increasing concentrations of carbon dioxide in the atmosphere would stimulate forest growth. Ultimately, plants absorb the gas from the air and convert it into energy-rich carbon compounds, i.e. sugars, through photosynthesis. They need these compounds to grow their biomass, such as stems and roots. A major international project is now conducting the first detailed exam-

ination of whether this assumption – more CO_2 equals more plant growth – actually holds. In the heart of the rainforest, not far from the Brazilian city of Manaus, numerous towers are under construction: 96 towers in total, each almost 40 meters in height. These towers will emit carbon dioxide, spreading it across sections of the forest. This will allow the researchers to simulate the elevated carbon dioxide concentrations expected by the middle of the century. Amazon Free-Air CO_2 Enrichment – AmazonFACE – is an open-air CO_2 fertilization experiment that, after around a decade of planning, has now entered the construction phase. The international team of researchers includes Anja Rammig, an expert in ecosystem modeling at TUM. "We provide the trees with far more CO_2 than usual, which allows us to measure the response of the whole ecosystem," she states. It is far from certain that the trees will actually grow better. As Rammig explains, it is also conceivable that tree growth will be stunted by nutrient deficiencies in the soil – which could occur if the increased growth leads to a reduction in vital phosphorus compounds.

approx. 50% higher CO_2 concentration

approx. 420ppm CO_2

40m

1

Measuring photosynthetic activity in leaves

Measuring the circumference and sap flow in the tree trunks

Monitoring soil and root respiration

Analyzing changes in belowground processes, here root samples

A field project, not a lab experiment

Anja Rammig reconstructs the complex processes at work in ecosystems on computers in order to understand them better and make forecasts. This work involves translating natural processes into numbers, such as the quantities of carbon exchanged between the atmosphere, the leaves and roots of a tree, and the soil. These ecosystem models rely on measurement values and figures that depict reality. Until now, such data has been lacking. Researchers have previously conducted laboratory-based experiments, subjecting specific plants to elevated CO_2 concentrations. However, conducting an open-air experiment on an entire section of forest – on the living object, as it were – is another proposition altogether. It is, as Anja Rammig explains, the only way to record natural processes in all their complexity. Not least because elevated CO_2 concentrations can also have other far reaching effects. ▷

Prof. Anja Rammig

studied biology at FAU Erlangen and received her doctorate from ETH Zurich in environmental science in 2005. She then worked as a postdoc at the University of Lund in Sweden. From 2008 to 2015, Rammig conducted research at the Potsdam Institute for Climate Impact Research (PIK). She was appointed to the Professorship for Land Surface-Atmosphere Interactions at the TUM School of Life Sciences in 2015.

Central measurement tower inside the CO$_2$ rings that are currently being built

More CO$_2$ – less rain?

Plants absorb CO$_2$ through stomates, which are tiny openings in their leaves. They also release water vapor through their stomates in a process called transpiration. If the air contains more carbon dioxide, the assumption goes, the plants can open stomates less. This would also reduce transpiration – which could become a problem for the entire Amazon rainforest. In effect, transpiration enables the forest to produce its own rain, as moisture that rises during the day pours down again at night. If transpiration rates from leaves fall, it could have a knock-on effect on the amount of rainfall. The result? A drier ecosystem. It is also these effects that the research team aim to investigate in the rainforest near Manaus.

The first towers have now been erected. Each plot under examination is surrounded by 16 towers. The plan is to examine six plots in total, with construction in two areas completed so far. The CO$_2$ taps are set to be turned on by the end of the year. The full AmazonFACE experiment is scheduled to run for around ten years, during which the research team will measure a variety of parameters – such as photosynthesis, water fluxes, tree growth, root growth, leaf growth and nutrient levels in the soil. The project is set to produce initial results at the beginning of 2024.

Anja Rammig hopes the project will provide a wealth of new data for her ecosystem models – models whose results are also incorporated into calculations of the Intergovernmental Panel on Climate Change (IPCC). "Our models can only ever be as good as the data we feed into them," she says. "The ideal scenario would be if, in a few years' time, the measurement results from the rainforest could be input directly into our models, enabling us to model processes in real time." This would make it possible to forecast the fate of the Amazon rainforest, and the process of climate change, far more reliably than is currently the case. ∎ *Tim Schröder*