2/2024

EVONIK
Leading Beyond Chemistry

ELEMENTS

Research. Knowledge. The future.

Growing Better

An issue about state-of-the-art agriculture

Smart farming

Information and communication technologies for a data-driven approach to agriculture

The mechanization of agriculture began in the 19th century with the development of the steam plow. This was followed by the invention of the tractor, which simplified many processes for farmers. Today agriculture is facing new challenges: Climate change and the increasing scarcity of natural resources are pushing conventional crop and livestock farming toward their limits. Digitalization is providing new approaches: With the help of software, artificial intelligence (AI), and sensor and robot technology, data is gathered in order to boost automation and precision farming. In this way, agricultural processes can be made not only simpler but also more efficient and more environmentally friendly—for example, through the use of satellite-controlled agricultural machines and the application of machine learning when sowing seed.

Artificial intelligence A collective term for technologies that automate intelligent behavior through the analysis of large volumes of data.

Precision farming Agricultural practice that serves to use resources more efficiently in order to minimize costs and environmental impact.

Machine learning A branch of artificial intelligence in which computers learn from data and improve their own performance as their experience increases.

DEAR READERS,

My grandfather grew up on the kind of farm that many people dream about: a few hectares of land in an idyllic river valley, with livestock, fields, and a bit of forest. The farming was done on the basis of experience, country proverbs, and the laws of nature—or rather, the whims of nature. When the weather was good, there was plenty of food on the table; when conditions were bad, there was not much to eat. If it got really bad, the farm's existence was at stake.

Modern agriculture is an entirely different matter. Today the farms are much bigger, but, above all, they are run differently. Their management is founded on science-based knowledge instead of gut feelings and country proverbs. Digital data and control technology are playing an increasingly important role.

Evonik is working on many projects whose aim is to produce healthy food efficiently while conserving the environment. For example, it's helping customers who are trying to find the best composition of animal feed at the given moment. The aim is to reduce the required amount of feed, keep the animals healthy, and enable them to metabolize their feed optimally. That conserves natural resources. The key to success is a wealth of digital data gathered over many years about raw materials for animal feed and digital analysis technology.

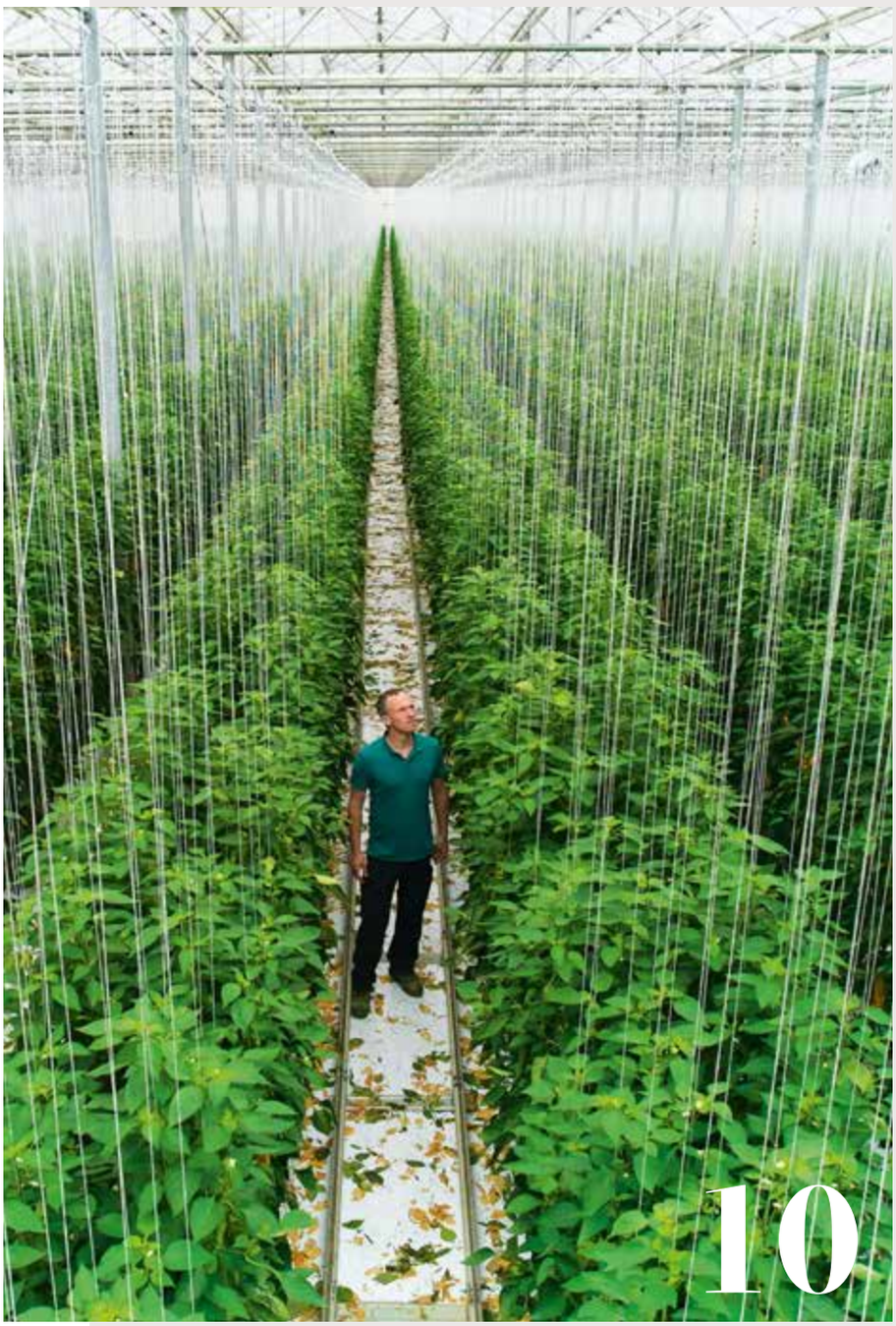
Digital technology is also promoting sustainability in the fields. Drones make it possible to spray large fields so precisely that the amount of spray agents used can be drastically reduced. Evonik ensures that the materials sprayed from above land exactly where they should and stay effective for a long time. Digital know-how keeps the closed water cycles in state-of-the-art greenhouses permanently clean, thus protecting valuable food crops.

In an age when even questions about nutrition are degenerating into religious wars, our scientific gaze gives you a different perspective on farming. My grandfather also implemented a change of perspective: Instead of taking over his father's farm, he became an economist. He has never regretted it.

If you have any questions, recommendations or criticisms, please write to me at elements@evonik.com

Jörg Wagner
Editor in Chief

All of the articles from the printed magazine, as well as additional current contents, are also available on the Internet at elements.evonik.com



High-performance, germ-free irrigation systems are crucial for vegetable farms like this one in the southwestern corner of Germany, where Tobias Jörg grows tomatoes and other crops

SMART FARMING

India is among the pioneering countries using drones in agriculture. In the future drones will also be used to spray crop protection agents

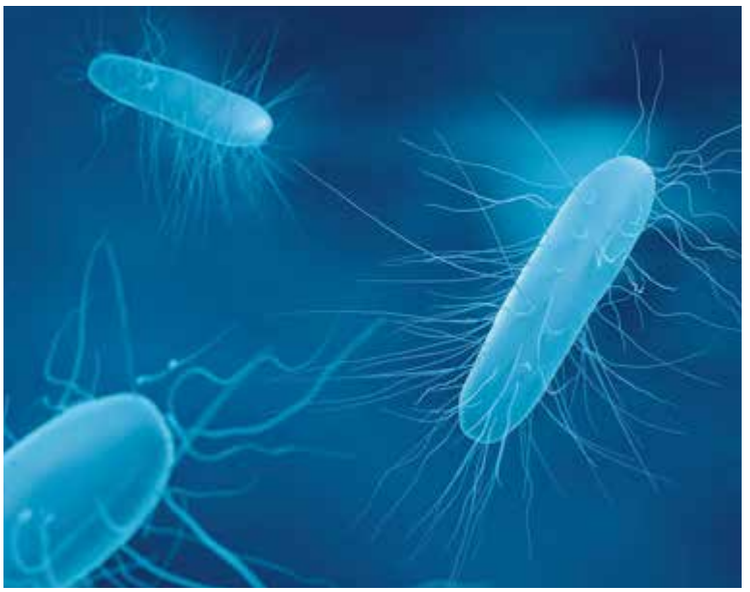
Near-infrared spectroscopy reveals the composition of the raw materials that are used to make compound animal feed at the Rothkötter production plant

At the Summit on Sustainable Development in 2015, the United Nations defined 17 goals that are known as the Sustainable Development Goals (SDGs). Evonik too is contributing in many different ways to supporting sustainable development. We present them here

Excessive consumption of resources and climate change are threatening the basis of life for many people. Increasing the sustainability of **consumption** and **production** should bring positive changes. Evonik supports this goal, for example through its increased use of renewable sources of energy.

Electricity from renewable sources such as **wind power** reduces CO_2 emissions and makes users more independent of fossil energy carriers. Evonik is pursuing an ambitious goal: It aims to draw 100 percent of its externally sourced electricity from green energy sources by 2030. A new power supply contract with the energy utility RWE marks a further important step toward this goal. The Kaskasi offshore wind farm in the North Sea will provide Evonik with 37.5 gigawatt hours of energy per year starting in 2028.

When viewed from a high altitude, the turbines of the wind parks in the North Sea look like cross-stitches on blue cloth. The North Sea is playing a central role in the international expansion of offshore wind energy. Plans call for it to supply Europe with electricity in the future as the "Green Power Plant of Europe". The power plants currently in use deliver a total of approximately 20 gigawatts of power; as early as 2030, the wind farms are expected to provide 120 gigawatts. That corresponds to the output of 86 medium-sized nuclear power plants.



The genus of *Clostridium* bacteria comprises numerous species. Some of them can be used to produce chemicals

A clever combination

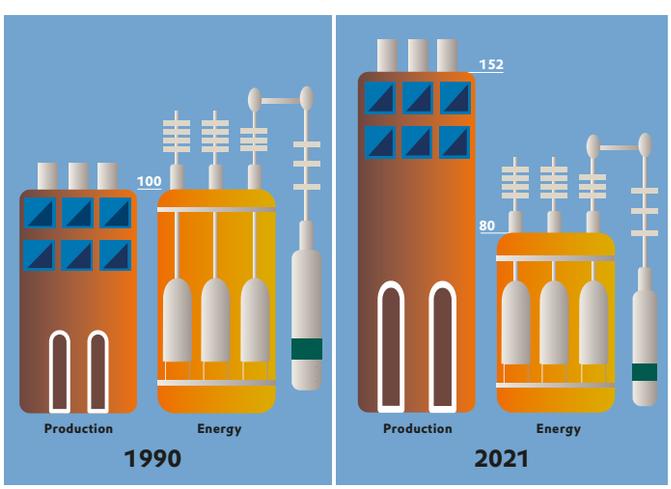
Combining electrolysis with fermentation makes carbon dioxide easier to use for industry

A research team at the Federal Institute for Materials Research and Testing (BAM) has further developed a technology that can be used to produce useful chemicals from CO_2 with the aid of bacteria and solar power. It has long been known that value can be added to carbon dioxide by fermentation and electrolysis. Until now, CO_2 was first reduced electrochemically to CO, which was then metabolized by bacteria into acids or alcohols. The two steps were carried out separately, as the catalysts in the electrolysis devices are made of gold, copper or silver and react sensitively to the fermentation liquid. In addition, the microorganisms do not tolerate the antibacterial effect of the metals very well. The BAM team has now managed to combine both steps. This is made possible by innovative carbon-based catalysts. This development shows the potential of combining biological and electrocatalytic processes and paves the way for the sustainable and decentralized production of CO_2-based chemicals.

THAT'S BETTER

Efficiency increase

Total energy consumption of the chemical industry in the EU, 1990 = 100



Over the past three decades, the chemical industry in the 27 member states of the European Union has made considerable efforts to improve its energy efficiency. Thanks to optimized production processes and the use of reusable resources, the industry has succeeded in reducing energy consumption by 20 percent since 1990 while increasing production by 52 percent. Overall, the share of renewable energy in the chemical sector continues to increase.

Source: Cefic/Eurostat

99.4

PERCENT

of visible light is absorbed by a deep black coating developed by researchers at the University of Shanghai for Science and Technology. Using atomic layer deposition, they alternately applied extremely thin layers of aluminum-doped titanium carbide and silicon dioxide to create an effective light barrier. The coating is resistant to environmental influences and can also be applied to complex surfaces, making it ideal for space telescopes, for example.

ELASTOCALORICS...

...is a new climate-control technology developed by a team of researchers at Saarland University. It uses wires made of a superelastic nickel-titanium alloy to heat and cool in an energy-efficient and sustainable way. Similar to muscles, these wires have a shape memory. They give off heat when they are stretched and absorb heat when they are released. This effect increases with bundled wires. The new process has enabled temperature differences of around 20 degrees Celsius to be achieved without any climate-damaging refrigerants. The prototype of a mini-fridge is already being operated using elastocalorics.

PEOPLE & VISIONS

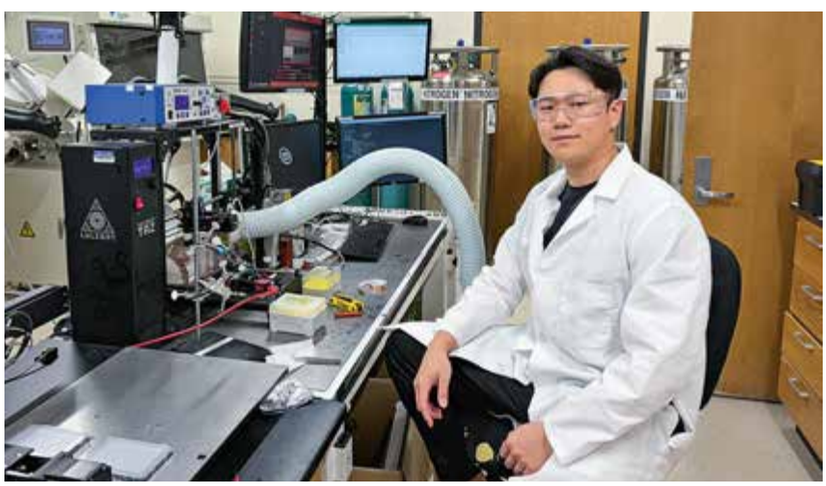
"The 3D printing process can change the molecular composition of the ink"

THE PERSON

Sanghyun Jeon is a research associate at the University of Illinois Urbana-Champaign (UIUC) in the USA. He grew up in Seoul, Korea, and has always been curious about light and color and the science behind them. After studying materials science at Korea University, he moved to the USA in 2021 to do his doctorate. "This field fascinates me because it provides answers to questions I've had since childhood—especially about the origin of colors and their relationship to light," he says.

THE VISION

As a rule, pigments are required for the technical production of colors. In nature, for example in bird feathers, colors are often produced by structural polymers. Inspired by this, Jeon and his team developed a polymer-based ink. The polymers can be arranged with a 3D printer in such a way that color impressions from blue to orange are created under UV light. "The printing process can change the molecular composition of the ink, resulting in different colors," says Jeon. Coatings might do without potentially toxic dyes in the future.



Safe storage

A new storage technology makes it possible to handle hydrogen chloride more easily

A team of researchers from the Free University of Berlin and Berlin Technical University has succeeded in safely storing and electrolyzing hydrogen chloride (HCl) in the form of ionic liquids. However, as hydrogen chloride is a corrosive gas and toxic in high concentrations, its transportation is very complex. The researchers in Berlin have now found a solution to this problem: They treated ammonium chloride salts with HCl and thus obtained an ionic liquid in which hydrogen chloride can be safely stored as a bichloride. This makes the gas easier to handle and transport. It can also be used directly for further synthesis, for example to obtain additional basic chemicals that are used in the production of plastics or silicones. Direct electrolysis of the bichloride to hydrogen and chlorine is also possible, and the new technology promises to make it particularly energy-efficient. Hydrogen is considered to be a key element for a successful energy transition, and chlorine is a versatile platform chemical.

GOOD QUESTION

What do modern batteries have in common with plants?

The working principle of the metal-air battery—the next generation of energy storage—is relatively similar to that of plant respiration. While photosynthesis resembles the charging process of the battery, cell respiration corresponds to discharging. Biological systems must breathe in order to survive: In plants, a chemical reaction takes place in which adenosine triphosphate (ATP) is produced from sugars, which serve as substrates and energy sources, and from atmospheric oxygen. Our battery uses magnesium as a substrate to generate electricity from oxygen and water. To produce the magnesium-air battery, we glued magnesium foil to paper and attached the cathode catalyst and the gas diffusion layer directly to the other side of the paper. The battery is light and thin, uses no toxic materials, and delivers impressive performance results.

Dr. Hiroshi Yabu is Professor and Director of Studies at the Advanced Institute for Materials Research at Tohoku University in Sendai, Japan

CLEAN CULTIVATION

In addition to water, a lot of data flows in today's greenhouses. Digital technology helps to minimize the number of germs in irrigation systems

Sustainable food production needs new forms of cultivation that use less land and water and require as few pesticides as possible. Evonik is helping to make this possible—with environmentally friendly chemistry and digital technology

TEXT **TOM RADEMACHER**

The natural enemies of the tomato plant have exotic names, such as *Pythium*, *Fusarium*, *Xanthomonas*, *Rhizobium*, and tomato brown rugose fruit virus (ToBRFV). And they lurk everywhere. "The tobacco mosaic virus, for example, could be carried into our greenhouse unnoticed on any smoker's hands," says vegetable grower Tobias Jörg. "Then there is a risk of total failure, the fruit becomes unsaleable, the plants die, all of them." That's why every walk in Jörg's greenhouse leads through a digitally monitored hygiene sluice, whose brush floor moistens the soles of shoes with disinfectant. Hand cleaning and disinfection are also mandatory before the turnstile allows access.

There is a great deal at stake: The greenhouse at Reichenauer Gärtnersiedlung in Singen near Lake Constance is 13 hectares in size, the equivalent of around 18 soccer fields under glass. Jörg and four co-founders established the company together in 2011. All five come from families that have grown vegetables for generations—but never on this scale: The five harvest around 900 tons of tomatoes, 2,000 tons of peppers, and three million eggplants here every year. Conditions are far different from those of the small farms of their parents and grandparents. Irrigation, fertilization, ventilation, heating—everything is automated here. The valuable fruits are harvested and packed by hand until well →

A reliable supply of water: Tobias Jörg's vegetable farm in Singen collects rainwater from the glass roof and stores it in ponds with a total capacity of 36 million liters

into November. This is followed by a thorough cleaning of the greenhouse and a final disinfection a few days later, before new plants are planted in January. “Once, in 2018, a *Fusarium* infestation extended from one year to the next,” recalls Jörg, who doesn’t want this to happen ever again.

Hygiene is extremely important in this state-of-the-art food production center. “The recirculating water in closed systems such as greenhouses enables pathogens to quickly spread everywhere,” explains Achim Marx. “Almost the only way you can deal with such a situation is with pesticides—if at all. That’s why we are working on preventative hygiene solutions to contain the spread of germs from the outset.” Marx is no farmer, but a trained biotechnologist who now works as a digital expert at Evonik Digital GmbH in Essen. Since 2017, the subsidiary has been developing new, digital business areas on behalf of the specialty chemicals company—including in agriculture.

ON THE PATH TO THE INTERNET OF THINGS

“Big data analyses allow us to better understand systems such as a barn, an animal organism or a greenhouse,” explains Marx. “This makes it possible to anticipate disruptive factors such as diseases and then take countermeasures earlier, more effectively, and usually much more gently.” This applies to animal production, where digital solutions from Evonik are already helping to improve the feed, intestinal health, and general well-being of pigs, chickens, and salmon in such a way that antibiotics, for example, become superfluous. Now digitalization is also set to protect tomatoes, lettuce, and other vegetables.

Evonik was recently nominated for the German Innovation Award for the holistic solution it has been developing since 2022. It combines knowledge from Evonik and the company’s own products for water hygiene with know-how from agricultural practice and new developments in areas such as big data and genetic analysis. Internet of Things connections, which allow telemetric remote monitoring and were developed in close cooperation with Siemens Digital Industries, are of great importance here.

Perhaps the most important innovation for Evonik itself, however, is the underlying business model. “We’ve managed to greatly automate and digitally optimize the monitoring of germs in the water as well as the countermeasures,” says Marx. “As a result, we can offer vegetable growers water hygiene as a service.”

The hardware essentially consists of a digitally controlled dosing unit with which infinitesimally small but effective quantities of an active substance such as hydrogen peroxide from Evonik can be fed into a water circuit. This could be a watering system for a chicken farm or

“Process automation and remote monitoring allow us to offer water hygiene as a service”

STEPHAN NEUMAYER, SENIOR MANAGER IN BUSINESS DEVELOPMENT ACTIVE OXYGENS AT EVONIK

Autonomous watering: In addition to irrigation, water recovery and disinfection are also fully automated in the greenhouse—which is currently still using UV light

Well watered: Tobias Jörg relies on efficient drip irrigation for growing tomatoes, peppers, and eggplants

drip irrigation in a large tomato greenhouse. Quantities in the parts-per-million range, i.e. less than one thousandth of a percent, are sufficient to eliminate harmful germs. By comparison, pharmacies offer hydrogen peroxide over the counter in a three percent concentration as a mouthwash for gargling.

COMPLEX TECHNOLOGY MADE EASY

The special feature of Evonik's new solution is that the dosing is intelligently controlled: Sensors collect water data in real time and complex data analyses help to determine the optimum dosage. This includes environmental parameters, information on operating processes and, in the future, cytometric analyses—i.e. precise determinations of germs. Sensors and dosing units communicate wirelessly via the Internet of Things. This allows Evonik to monitor all data centrally and let the system learn. "The user is completely unaware of this complexity. It remains simple for him," says Marx. "At the same time, our system learns on its own and guides users through the handling in a very straightforward way."

This aspect shouldn't be underestimated. "We are also meeting the demand for process reliability and convenience," says Frank von der Haar, with whom Evonik collaborated to develop this "all-round carefree package". "Nobody wants to worry about water hygiene. This often only changes when something goes really wrong," says von der Haar, an engineer based near Osnabrück. He knows this field inside out. He set up his own business around 20 years ago with systems for water disinfection in agriculture and sells them throughout Germany. "Word gets around when someone suddenly achieves significantly better results through water hygiene alone," he says. Marx didn't come across von der Haar and water hygiene entirely by chance. Marx had previously visited several farms for his Essen-based employer. "I kept noticing this sticker," he says. "It said: Agricultural hygiene—water technology—Frank von der Haar."

This sticker can also be found in Singen. There, von der Haar helped to get the *Fusarium* outbreak at Tobias Jörg's greenhouse under control in 2018. Today, irrigation is carried out almost exclusively using rainwater, which is caught by the glass roof, collected in three large ponds, and disinfected with UV light. "For us, the automated solution from Evonik is an interesting further development in water hygiene," says Jörg. "Above all, it's interesting to know which pathogens in the water you need to ramp up your defenses against." To make this possible, Evonik worked with the University of Applied Sciences and Arts Northwestern Switzerland in Basel to demonstrate how the "fingerprint" of certain harmful germs in water can be determined almost in real time. →

Farm of the future: In Jülich, Professor Ulrich Schurr is researching plants and new cultivation technologies

"Shorter transportation routes are also needed in Europe"

PROFESSOR ULRICH SCHURR,
HEAD OF THE FZJ INSTITUTE OF PLANT SCIENCES

Using a PCR device and a flow cytometer, *Rhizobium rhizogenes* could be identified accurately and almost fully automatically in the water. The bacterium is responsible for crazy roots syndrome, in which plants suddenly develop uncontrolled roots. "If we know what we are dealing with, we can take more effective countermeasures," says Jörg. "After all, not every germ is equally problematic. But by the time we have to send in samples and wait for results, it's usually too late."

FOCUSING ON ROOTS

At Forschungszentrum Jülich (FZJ) near Aachen, the causes of pest infestations are being investigated further. In the research greenhouse of the Institute of Plant Sciences, Professor Ulrich Schurr and his team of 170 people are working on new concepts for more sustainable agriculture. "New and improved cultivation methods can help to produce food more sustainably and, most importantly, to adapt production to changing conditions, such as climate change," explains Schurr. The work in the research greenhouses extends from the German sugar beet to the "tropical potato" manioc. Schurr has just given a delegation from East Africa a tour of the experimental facilities.

One of the scientists' specialties is the hidden life of plants underground—the "hidden half", as they call it here. "We don't just look at the shoot, by which I mean everything that grows aboveground, but instead take an especially close look at the roots," says Schurr. To this end, his team uses technologies that allow them to watch the roots grow and even track the flow of water and nutrients within the roots. The Jülich Rhizotron facility is unique. It consists of almost 1,000 diagonally arranged plant containers with a transparent base and several robots that move back and forth between them. The roots of the plant grow downwards along the pane. Several times a day, the robots take each container out of the facility in order to take a high-resolution photo of it.

Using tens of thousands of such images and AI-assisted image analysis, Dr. Vitalij Dombinov is researching, for example, how to make a fertilizer derived from sugar cane ash—an abundant agricultural residue in Brazil—palatable to the country's crops. MRI and PET machines are located next to the facility. Both methods, magnetic resonance imaging and positron emission tomography,

are otherwise more familiar from medicine. In Jülich, the researchers are using it to show, for example, how beets grow, how they store carbon in the form of sugar, and how certain diseases hinder this process.

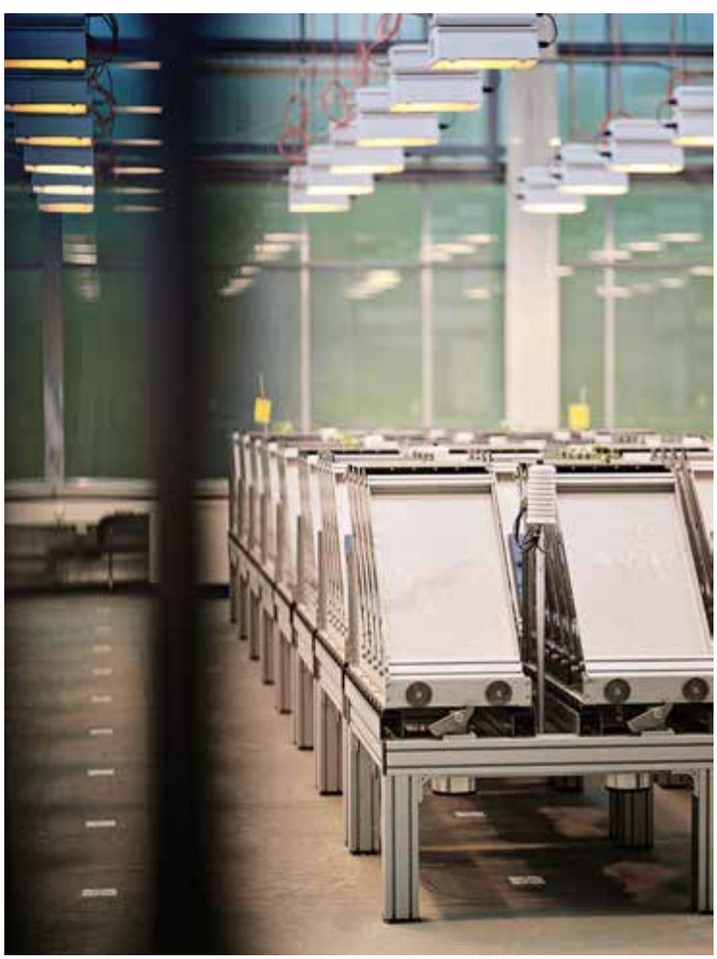
On behalf of Evonik, the scientists in Jülich are now testing what Evonik's innovative service approach can do for plant and root health. The goal is not just to obtain scientific evidence—the FZJ is an important interface to practical applications. "We translate research findings into practical recommendations and methods for agriculture," explains Dr. Arnd Kuhn, one of the most experienced members of Professor Schurr's team. The FZJ regularly works with horticulturalists, farmers, and breeders in the region to test such new technologies under real-life conditions.

A JOB FOR HYDROGEN PEROXIDE

The experiments also include the use of hydrogen peroxide to combat germs. "Our new approach works with any standard disinfectant," says Stephan Neumayer. "But hydrogen peroxide has clear ecological advantages." Neumayer is a senior manager in Business Development at Active Oxygens, the Evonik business line that primarily produces hydrogen peroxide. With an annual capacity of over one million tons and around 20 production sites, Evonik is one of the world's largest manufacturers of hydrogen peroxide.

This compound of two hydrogen and two oxygen atoms reliably decomposes harmful germs and breaks down into water and oxygen. "This means that no harmful residues remain, as can be the case with some other disinfectants," says Neumayer. For this reason, hydrogen peroxide is used as an environmentally friendly bleaching agent in paper and pulp production. It is also frequently used as a disinfectant in the food industry and even as a sustainable rocket fuel in civil space travel.

At Jülich, the hydrogen peroxide required is produced in the research greenhouse itself. A refrigerator-sized device from HPNow is sufficient for this. It is the latest generation of devices from the Danish manufacturer, in which Evonik has held a stake since 2017. Inside, a catalyst is used to produce one percent hydrogen peroxide. All you need is air, a water connection, and a power socket. "The quantities that the device delivers are com- →



Underground: Forschungszentrum Jülich focuses in particular on the hidden life of roots

pletely sufficient for this application," says Neumayer. "We are not primarily interested in large new sales markets for hydrogen peroxide." Instead, Evonik markets water hygiene as a service at an all-inclusive price. For a fixed amount per cultivation cycle, the specialty chemicals company ensures that the water remains "clean". "This way of thinking is still young in a company that has been manufacturing and selling chemical products for generations," says Neumayer. But the trend is towards "anything as a service". Instead of just chemical products, Evonik will market the complete solution as a package, consisting of product, technology, and know-how.

SUSTAINABILITY ON THE PLATE

With this package solution, Evonik is also accommodating an important trend in agriculture and food production. Cultivation methods must become more sustainable, adapt to changing climatic conditions, and at the same time meet high consumer demands. Conventional cultivation requires vast areas, lots of water, large amounts of fertilizer, and usually pesticides. Organic farming is considered more environmentally friendly, but requires more land because the yields are lower. Because consumers also expect flawless vegetables and a full range of products throughout the year, there is a lot of waste and long transportation routes. Asparagus flown in from South America pollutes the climate, but so does every locally produced head of lettuce that ends up limp in the trash.

Controlled environment agriculture (CEA) could offer a solution. CEA includes high-tech greenhouses like the one at Lake Constance, in which nutrients, irrigation, temperature, humidity, and much more are tailored as perfectly as possible to the needs of crops such as lettuce, tomatoes, peppers, and eggplants. In many cases, CEA even manages without soil because the nutrient solution flows directly around the roots of the plants. Instead of the sun, LEDs provide the light—and always in

Smart box: Achim Marx (center) demonstrates the digital dosing unit specially developed for AQUOPROTECT to Jülich researchers

Hydrogen peroxide produced on site keeps the irrigation system in Jülich free of germs

the optimal wavelengths for each growth cycle. In vertical farming, the plants grow on multiple levels above one another to save space.

At 31,000 square meters, the world's largest vertical farm is currently located in Dubai. Lettuce and other leafy vegetables thrive here all year round on huge shelves, while the sun broods over the desert outside. Until now, the Emirates have imported around 90 percent of their food. Locally produced vegetables could be a more sustainable addition, despite the high complexity of vertical farming. More and larger vertical farms are already being planned, and Siemens equipment is installed in many of them. "But shorter transportation routes are also needed in our conurbations here in Europe," says Schurr. Vertical farming would also be an opportunity specifically for the structural transformation of the Rhenish lignite mining region. Moreover, water scarcity is increasingly becoming an issue here as well.

SMART COUNTERMEASURES

Vertical farms can save 95 percent or more water. After all, nothing seeps away and even every drop that evaporates is fed back into the cycle. That's how the farm in Dubai saves around 250 million liters of water per year compared to conventional cultivation. "These cycles are highly efficient, but also mean that the same water flows around practically every root," explains Marx. "In the worst case scenario, harmful germs quickly spread across the entire cultivation area."

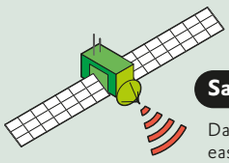
Tobias Jörg also likes the idea of being rid of this worry once and for all—with guaranteed germ prevention practically on subscription and digitally at the touch of a button. So far, the water cycle in Singen has been disinfected with UV light and by the company itself. However, the facility is slowly getting on in years. And it certainly doesn't learn on its own. "At the same time, we are now dealing with ever new and increasingly resistant pathogens from all over the world," says Jörg. ToBRFV, for example, which tomato growers fear, was only detected in Germany for the first time in 2018. So it's high time for a smart countermeasure that works preventively, is tailored to plants, processes, cultivation parameters, and the actual amount of germs—and is also fit for future challenges thanks to digitalization, big data, and artificial intelligence.

Tom Rademacher is a freelance journalist based in Cologne. He writes about scientific and industrial topics, among others

My little server farm

In many regions of the world, farmers use digital support in their work. From the analysis of raw materials for feed to the monitoring of livestock and the recording of material flows, modern technology has become indispensable. Here's an overview

INFOGRAPHIC **MAXIMILIAN NERTINGER**



Satellite

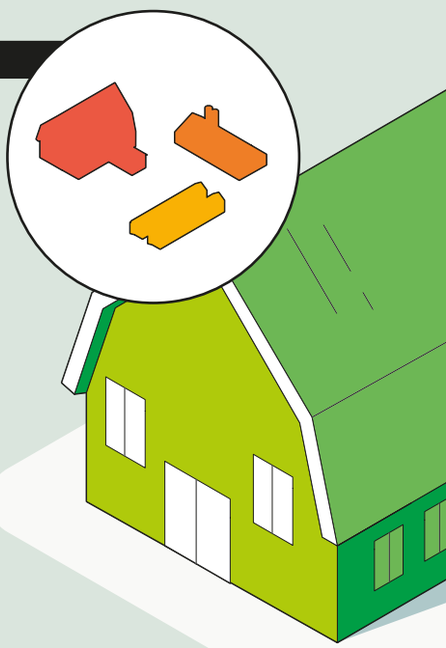
Data from space makes it easier to predict plant growth, crop yields, and the spread of pests. The data is also used to navigate agricultural equipment.

IN THE OFFICE

Digitalization optimizes operations

Digital twin

Software helps the farmer plan work processes, material flows, and energy use. Changes can be simulated before investment decisions are made.

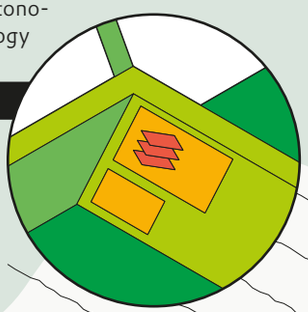


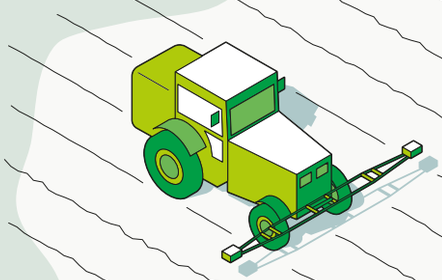
IN THE FIELD

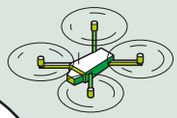
Autonomous and semi-autonomous agricultural technology

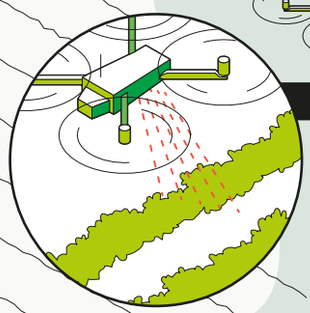
Tractor

Agricultural machinery is controlled with the help of terrain maps, satellite images, and sensor data. This enables the amount of fertilizer to be adjusted precisely to the needs of the plants, for example.



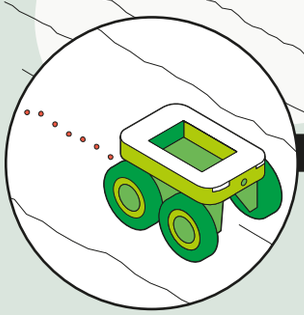






Drone

UAVs are increasingly helping with observation (e.g. of wild animals in the field before mowing) and the precise application of crop protection agents.



Robot

Agricultural robots assist with light work such as sowing, weeding, and pest control. Some of them are AI-assisted and determine their locations with the help of built-in cameras.

IN THE PASTURE

Data collection and analysis

Tracking

Ear tags enable animals to be monitored around the clock. For example, a motion sensor measures how long a cow ruminates. In this way, digestive disorders can be detected at an early stage.

IN THE BARN

Digital monitoring and control

Data collection

Livestock farmers are supported in their daily work by data from cameras, microphones, and sensors. This allows pig diseases to be detected at an early stage, for example.

Robotics

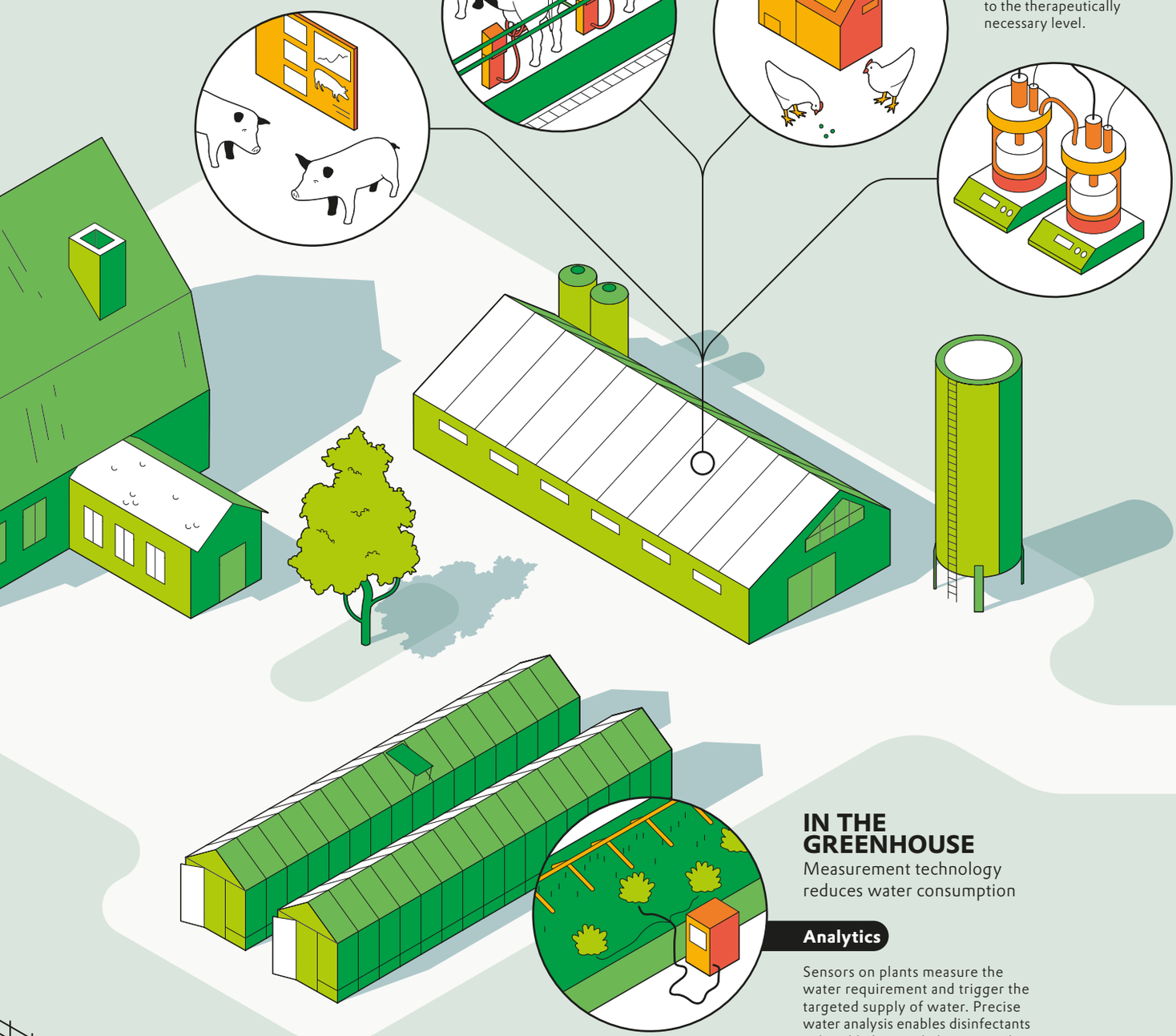
Robots milk the cows and sensors monitor the livestock and the milk. Both the health of the animals and the quality of the milk are continuously recorded.

Raw material analysis

The composition of compound feed is optimized with the help of analytical technology and access to databases so that the animals receive the best possible care.

Simulation

Data from a laboratory model increases the understanding of microbiological processes in chicken intestines and helps to reduce the use of antibiotics to the therapeutically necessary level.



IN THE GREENHOUSE

Measurement technology reduces water consumption

Analytics

Sensors on plants measure the water requirement and trigger the targeted supply of water. Precise water analysis enables disinfectants to be added as needed to ensure the cleanliness of the irrigation system.

“If you use digitalization in the right way, it simplifies processes significantly”

ANDREAS DÖRR, FARMER
AND CEO OF DOERR-AGRAR

Thanks to smart technology, cows can be milked efficiently and crop protection agents can be precisely applied. At the same time, data gathering and processing is facing agricultural operations with huge challenges. Andreas Dörr, a farmer, and Johann Meierhöfer, an expert from a farmers’ association, talk about the opportunities and limits of digitalization

MODERATION **JÖRG WAGNER** & **CHRISTIAN BAULIG**

Mr. Dörr, you grew up on a farm. Do you still remember how your father used to plan the field work?

ANDREAS DÖRR When I was a boy, all of that was still analog. My father watched the weather forecast on television, and after that he would plan when he would plow, fertilize or harvest. However, he switched to relying on modern technology early on and used software applications. On our family-operated farm, we’ve been digitally maintaining a field file, in which we keep track of all the agricultural work done on each plot of land, for the past 23 years.

Today you cultivate more than 1,400 hectares, and your operations are fully digitalized from start to finish. You optimize the fertilization process with the help of near-infrared analysis, precisely measure the moisture of the grain growing in the field…

DÖRR We’ve even developed a digital twin of our agricultural operations. It’s a cloud-based application that we use for the daily planning in order to optimize our processes and improve the quality management. We’ve also got a smart grain warehouse and a smart filling station, and the vehicles we use for working the fields are computer-controlled. The structure of our operation compels

“Some farmers are wondering if they want to go to all of this trouble”

JOHANN MEIERHÖFER, HEAD OF THE PLANT PRODUCTION/ENERGY DEPARTMENT OF THE GERMAN FARMERS’ ASSOCIATION

us to work efficiently. Our company’s office is located in Ostheim vor der Rhön, and the farm operations are 30 kilometers away in Oepfershausen. Digitalization has been important for us for a long time, because we need to have access to all of the information from everywhere. I’ve programmed a number of apps and applications myself. I have new ideas all the time—and I enjoy working with this topic.

Mr. Meierhöfer, is this what the future of agriculture will look like?

JOHANN MEIERHÖFER Unfortunately, there’s a huge gap between the people who are marching way out in front like Mr. Dörr and the vast majority. German farmers are very innovative, and many of them would like to do much more—but many of the basic requirements are missing. A fourth of German farmers use technologies that are related in some way to precision agriculture, but this proportion has barely increased in recent years. Evidently there are obstacles that the remaining farms cannot overcome. The policymakers often forget this fact very quickly if they are always presented only with examples such as Mr. Dörr’s farm.

According to a study conducted recently by the Bitkom association, large-scale farms believe that digitalization mostly offers them opportunities. Smaller operations have a more vivid awareness of the risks involved. Is digitalization in agriculture a question of size?

MEIERHÖFER Small farms use it successfully too. I know farmers with operations covering 50 or 100 hectares who are grappling intensely with digital technologies—for example, because they are raising livestock, an area where digitalization makes a lot of sense. Conversely, I know of large farms in regions such as Brandenburg, whose owners got involved very intensely with the topic 15 years ago and in some cases hired additional personnel who dealt only with the field file, yield analyses, soil samples, and precision application—and these owners eventually stopped using these technologies.

Why did that happen?

MEIERHÖFER In many cases, these activities don’t yield any direct added value. So it’s not primarily a question of size. Instead, it depends on the people in charge. Admittedly, it’s often easier for a larger farm to make the necessary investments in digital technology. →

Andreas Dörr, 41, is the CEO of Doerr-Agrar. In the German state of Thuringia, the company cultivates about 1,400 hectares, including 950 hectares of arable land and 450 hectares of grassland. Dörr, an agricultural engineer, uses many smart technologies. In 2023 he received a Bavarian Digital Award (second prize). In addition to working at his family-owned company, Dörr advises industrial companies and makes presentations to farmers

What kind of figures are we talking about in your case, Mr. Dörr?

DÖRR We invest about €20,000 annually in digital applications, meaning both hardware and software. However, our farm is a special case, because industrial companies make lots of equipment and programs available to us so that we can try them out. The time I need to invest as an operations manager is more important than the money involved. I need to understand the technology, read up on the documentation, negotiate with service providers, and share data. Nowadays a farmer is not just a crop producer or livestock owner but also an IT administrator and a geodata processor. Many of the applications we use are very complex.

Farmers have had to deal with new technologies since time immemorial. What makes digitalization so special?

DÖRR Farmers are being bombarded with so many things today. We're experiencing upheavals resulting from climate change, fluctuating demand structures, and the desire for greater environmental compatibility on the part of policymakers and society as a whole. Digitalization is now a further step in this structural transformation. It can make the future of many farms easier—but also pour oil on the fire in the course of the ongoing structural transformation.

MEIERHÖFER Besides, it requires lots of preconditions. Take precision fertilization, for example. Fifty years ago a farmer would drive to the dealer, have the dealer pour the fertilizer into his trailer, and then drive out into the field. He chose the settings of the fertilizer spreader according to his past experience. Perhaps he drove a bit slower in one place and a bit faster in another—and that was the end of it. Today I have to start by purchasing the suitable technology. Nowadays a state-of-the-art tractor already receives a satellite signal as a rule, but I also need a fertilizer spreader that can make use of an application map. Next, I have to consider on which basis to proceed. Should I use the German soil inventory—that is, the soil maps that were created about 90 years ago for all of the agricultural land utilized in Germany? Do I place my trust in conductivity measurement, satellite images or a sensor? At that point some people might wonder if they want to go to all of this trouble.

DÖRR You're touching a sore spot here. At our farm we're currently running a research project on precision fertilization. There are so many factors coming together in the soil that we can't yet represent by means of data. We've participated in many experiments over the past ten years, but so far there hasn't been any technology that impresses me. The experience my father brings to the farm operations, his connection with the different soils, his familiarity with the region and how its climate behaves—all of those things are much more important.

Just a moment, are you saying that digitalization as a whole is the wrong approach?

DÖRR No, I have a different perspective when it comes to precision crop protection, for example. The precision application of crop protection agents can be determined according to simple parameters: More spray has to be applied to the plant stock where it's dense than where it's sparse. Digitalization can help us make the right decisions for improving soil quality, cultivation techniques, and livestock farming. We farmers have a long-term interest in that, because only healthy soils yield good harvests and only healthy animals provide high outputs.

Digitalization takes time. But you're also saying that it enables you to save lots of time.
DÖRR That's right. It doesn't always have to be a fantastic solution that uses satellite-supported technologies. The paperless office, in which documents are scanned and digitally filed, can already help a lot. Farms do direct marketing via webshops and advertise their products on social media. If you use digitalization in the right way, it simplifies processes significantly. You just have to choose what you need from the wide range of applications.

Is the change of generations promoting digitalization?
DÖRR It certainly is. It's just the same in every area of life: When the children are using something new, the parents are forced to deal with it too. My father doesn't understand the details of how some of the things we're introducing actually work. But he thinks it's cool that when he's on the road he can pull his mobile phone out of his back pocket and look at our stock ledger app to find out how much wheat has already been threshed today and how much of it has already been brought to the grain store.

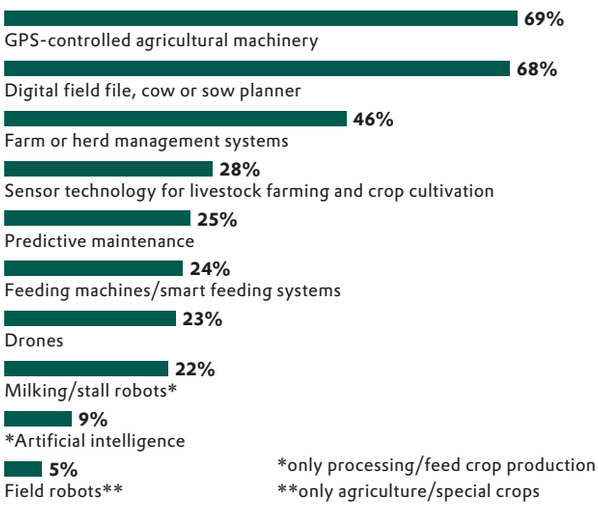
Shouldn't it be up to industry to develop solutions that are more user-friendly and make life easier for the farmers?
MEIERHÖFER Unfortunately, that's not the case. Until now, one big problem has been interoperability—the ability of machines to communicate with one another even if they come from different manufacturers. It's true that standards for such communication have existed for decades—but I remember some very intense discussions a couple of years ago about the fact that the brand X fertilizer spreader didn't want to work together with the brand Y tractor. Fortunately, that has been changing recently. Change is also afoot in the area of software. For a long time, manufacturers tried to sell solutions that were as comprehensive as possible. But farmers don't always want to buy everything from a single source. Lately we're seeing companies cooperate with one another—something they had refused to do for a long time. This gives me hope that the system is becoming more permeable.

Does this mean that customer needs are being identified more effectively?
MEIERHÖFER At least it comes down to business models that benefit not only the solution provider but also the farmer who uses a product or a software. For →

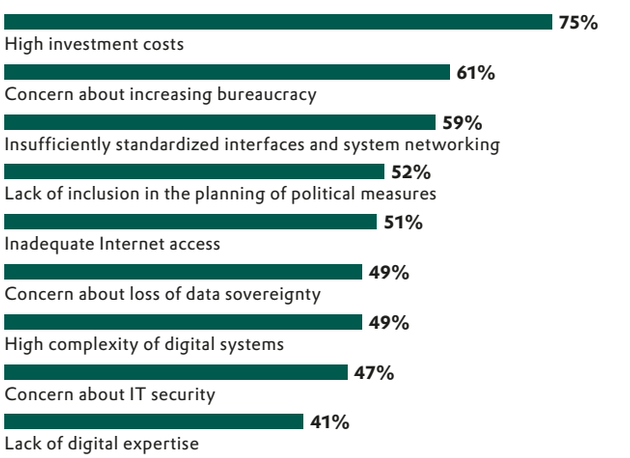
"Nowadays a farmer is also an IT administrator and a geodata processor" ANDREAS DÖRR

Digitalization among German farmers

Which technologies or processes are you already using?



In your opinion, what obstacles are most strongly slowing down the digitalization of agriculture?



A survey of 500 German farmers
Source: Bitkom, as of 2024

“Successful digitalization is not primarily a question of the size of the operation”

JOHANN MEIERHÖFER

Johann Meierhöfer, 51, is the head of the plant production/energy department of the German Farmers’ Association in Berlin, where he is also responsible for the area of digitalization. As an agricultural engineer, he previously worked on several large-scale farms as an operations manager or general manager. He was also the head of the Department of Agriculture of the Teltow-Fläming district of the state of Brandenburg

example, automatic steering systems make work easier for the driver—and that’s a clear benefit for operations. That also applies to milking robots, which you can find on many family-operated dairy farms today. This is also due to the fact that the robots make it easier to monitor the milk quality and thus the health status of the cows. Another very important factor is the benefit for the farmer, who can go to a birthday party on a Saturday afternoon without having to disappear into the cow stall at 5 p.m. The improvement of individuals’ quality of life, especially for family-run operations, should not be underestimated. Every technology that enhances efficiency or improves the quality of life will quickly become standard practice.

Does this mean that in the future farmers will buy fewer products and more services?

MEIERHÖFER I can imagine contractors and machinery pools being interested in offering not only fertilization for fields but also optimized fertilization recommendations—as long as they aren’t too expensive.

DÖRR However, in the future this kind of thing could also be handled via artificial intelligence. The farmer would then communicate with an application that provides answers adapted to his needs. If he’s sitting in his tractor equipped with a mower in a pasture, the system could provide him with relevant information such as: “You are located in a biosphere reserve, so you can only mow here from June 15 on. Please leave ten percent of the grass untouched and mow from the center outwards so that deer and small wild animals have an escape route.” Currently, I can only turn to advisors, research institutes or other farmers if my yield of wheat has remained stagnant for years and I have to struggle more and more often with early-summer droughts. But it would be fantastic if there were an AI that’s fed with all of this information! In that case I could get an answer that sounds something like this: “Farms in climate regions similar to yours, which have similar crop rotations and cropping patterns, have switched from plowing to direct sowing,” for example. I would have concrete answers and could research the situation more deeply.

MEIERHÖFER This is something that may happen one day. But in Germany we still lack the fundamental conditions for sharing this data and putting it to active

use. Even data that are basically public are hardly ever made available to the agricultural sector in a usable form. Farmers primarily think in the long term, that's part of their job description. But like all businesspeople, their available time and financial resources are limited. So I have to consider what can help me here and now. If it doesn't bring me at least a medium-term effect, I won't use it.

When consulting companies offer customized AI solutions, we end up very quickly in the business model of the big digital companies that operate according to the winner-takes-it-all principle. A company that does this well and is recommended by one farmer to another is soon the Lord of the Data—and that's no longer the case for the individual farm. Wouldn't that be very risky for you?

DÖRR I would certainly be willing to make my production data available in an anonymized form, but I'd like to decide for myself which information I share. And I don't believe in companies that present themselves as "full-range suppliers". They lock the farmer into their system of technology and know-how and don't leave him any other choice than to buy their machines, their seeds or their crop protection agents. In the USA today, there are many farmers who can no longer independently plan the use of herbicides on their land because they haven't had to deal with this matter themselves for years. I'd like to see a system that trains the farmer and makes him more resistant instead of dependent and ignorant. I tend to see AI as a system that supports decision-making and trains me on a permanent basis.

MEIERHÖFER When it comes to data, we have to take a healthy middle course. It's ultimately the responsibility of every farm owner and every business manager to say, "I would like to share this or that data set, but not this or that other one." In Europe there will be a number of things in the Data Act and the corresponding implementation regulations that will be different from what's going on in the USA. There I'm already observing some farmers adopting a very open-hearted attitude. If a single large company knows all the data about my farm operations, that increases the likelihood that this company will use this data to judge my creditworthiness or calculate individual prices for me. It doesn't matter how often the company tells me that it's not doing it.

A role model: Parked in Johann Meierhöfer's office is the model of a self-propelled agricultural sprayer that could precision-spray crop protection agents

In some technologies Germany and Europe were the leaders—and were overtaken later on by other regions of the world. Are you afraid that other countries will digitalize their agricultural sector faster and put European farms under pressure?

MEIERHÖFER There are many factors in the area of production in which we are at a much greater disadvantage compared to the rest of the world. The fact that digitalization is not yet being used by the entire agricultural sector in Germany is not a serious regional handicap. To express it somewhat provocatively, if I'm a trained agronomist, in a pinch I can manage my farm even without digitalization. This has worked over the past 50 years, and it will work in the next 50 years as well. When it comes to the office work related to farm operations, things become more problematic. In this area I'm especially concerned about the excessive government bureaucracy. Managing it without digital assistance is becoming difficult.

DÖRR I also believe that we can stand our ground in international comparisons. There's a reason why many innovations in the area of agriculture are coming from Europe. The big agricultural technology companies are testing and developing lots of innovations in Germany, England, and New Zealand. That's because they know that if an innovation works in Germany and these other countries, and if the farmers here are satisfied, that means it also works in other parts of the world. —

BON APPÉTIT

Modern compound feed has to fulfill many requirements. Not only must it provide animals with healthy nutrition and minimize the excretion of nitrogen—its production should also consume as few raw materials as possible. Evonik's feed analyses and essential amino acids are making an important contribution to sustainable animal husbandry

TEXT **ANNETTE LOCHER**

The Rothkötter compound feed plant in Haren is located right next to the Eurohafen harbor on the Ems River. Barges deliver tens of thousands of metric tons of raw materials here every year

It's already late afternoon, and the Eurohafen harbor in Haren (Ems) isn't very busy. Only the Rothkötter company's jetty has two barges still moored to it. Carrying a white plastic bucket and a long metal rod, a compound feed miller leaves the adjacent plant and quickly walks the few meters to the water. After the miller has a brief talk with the captain, the latter opens the cover of the cargo hold to reveal 1,000 metric tons of wheat. The miller boards the barge and pushes the sampling rod into the grain at different depths in several places according to a predetermined pattern. He then fills the samples into plastic bags.

Rothkötter Mischfutterwerk produces chicken and pig feed at three locations in Germany. The most important raw materials for this feed include grains such as wheat, oilseeds such as soy or rapeseed, and by-products from food production. Feed is a key factor when it comes to the profitability and sustainability of livestock farming. The origin of the raw materials, their respective composition, and the addition of additives have a decisive influence on animal welfare and meat quality. In order to create feed that is optimized in all these respects, manufacturers need to know the exact composition of all the components. That is why no company can do without state-of-the-art analytics. Rothkötter relies on Evonik's feed analytics to exploit a stream of constantly →

Do the soybeans lack anything? Modern analytical technology and the use of big data provide information about the quality of feed raw materials

A compound feed miller takes samples of the wheat delivered on a barge and fills them into bags

new raw materials, including many from the local area. The laboratory at the Rothkötter compound feed plant in Meppen, just a few kilometers away, is located directly at the factory entrance. A sampler hovers above the scales on which all trucks delivering raw materials must stop. Maria vor dem Brocke can control the sampler remotely from the laboratory building. She takes samples, inspects them, and determines some simple parameters such as the moisture content. She also prepares raw material samples—including those taken at Eurohafen—for near-infrared (NIR) analysis.

A device the size of a conventional desktop printer takes less than a minute to analyze a sample (see the info box on p. 30). The result can be seen on the connected monitor in the form of colored curves. Once the measurements have been completed, vor dem Brocke transmits all the results to Evonik online. Fifteen minutes later, the computer tells her the content of protein, fat, fiber, sugar, phosphorus, ash, amino acids, and other components in each sample.

This knowledge is crucial for Christian Emthaus, the managing director and head of Rothkötter's three compound feed plants. "We know the nutritional requirements of chickens and pigs in their respective development phases very well, and we tailor the feed to these requirements," he says. Emthaus always has to adjust the composition of the ingredients, because plant-based ingredients vary greatly depending on the variety, origin, weather, and type of storage. Moreover, the availability of raw materials also fluctuates enormously.

The protein content of the feed is a very important parameter for the growth of the livestock. "The amino acid composition is crucial here," explains Dr. Maike Naatjes, an agricultural engineer specializing in animal nutrition. She works at Evonik's Animal Nutrition business line and provides technical support to customers in Europe, the Middle East, and Africa. She is also in close touch with Christian Emthaus.

CUTTING PROTEIN CONTENT

Of the 21 different amino acids that make up proteins, animals are unable to produce eight themselves. These amino acids are known as essential amino acids and they must be supplied in sufficient quantities via the feed. "As soon as one of the required essential amino acids is used up, the animal can no longer utilize the excess of the other protein components that are present," explains Naatjes. "They have to be metabolized and excreted in the urine." This effect must be avoided for several reasons: Protein-rich raw materials are expensive and take up agricultural land. The animals' excrement contributes to the overfertilization of soil and water. Moreover, the proteins put the animals' organisms under unnecessary strain.

In the Rothkötter laboratory, Maria vor dem Brocke uses near-infrared spectroscopy to analyze raw feed materials

In order to achieve a balanced amino acid ratio with less raw material, many manufacturers add small amounts of pure amino acids to the feed. Chickens are most often deficient in methionine, while pigs are first and foremost deficient in lysine. Evonik offers the three most important amino acids in its product range.

But how much of which additive is needed in each mixture? Before the introduction of NIR analysis, feed manufacturers worked with data from complex wet chemical analyses that companies such as Evonik carried out on raw material samples from all over the world and published once a year. "Back then, we knew, for example, that European wheat contains nine to 13 percent protein and that the majority of samples contain ten to 11.5 percent," says Emthaus. To be on the safe side, he always set the quality of the raw material slightly lower than the known average in order to get an approximate value for the methionine requirement, for example.

Today, with the support of fast NIR technology, the formulation of animal feed is daily precision work. Large manufacturers such as Rothkötter have their own NIR devices but rely on Evonik's support for evaluating the analysis data. This is because NIR analysis is an indirect method that can't determine the total quantity of the components of the raw material. In order to correctly evaluate the measured spectra, data sets with the known content or concentrations of a substance are needed. Evonik has built up and constantly expanded these data sets over decades. "In the laboratory, we've thoroughly analyzed millions of samples of more than 60 different raw materials from all over the world," says Naatjes. They form the basis for the company's AMINONIR® service.

Rothkötter uses NIR analysis on a random basis for known suppliers and for deliveries by truck. Deliveries of raw materials by barge or rail, which involve much larger quantities, are checked more closely. In such cases, Managing Director Emthaus sometimes waits for the results of the analysis before deciding which silo to store the raw material in. The components are then processed and mixed fully automatically in the multi-level feed mill. In one day, more than 1,000 metric tons of compound feed are produced in this way at the Meppen site.

By combining state-of-the-art analytics and a growing range of additives, Rothkötter has been able to steadily reduce the protein content of the feed over the years. "Before the first amino acid, methionine, was available as an additive, poultry feed, for example, contained around 30 percent protein," says Emthaus. Today— →

with the addition of several amino acids—it is only 19 percent. Evonik calls this concept "low-protein diets," in which the animals' amino acid requirements are met with less crude protein.

REDUCING NITROGEN EMISSIONS IS THE GOAL

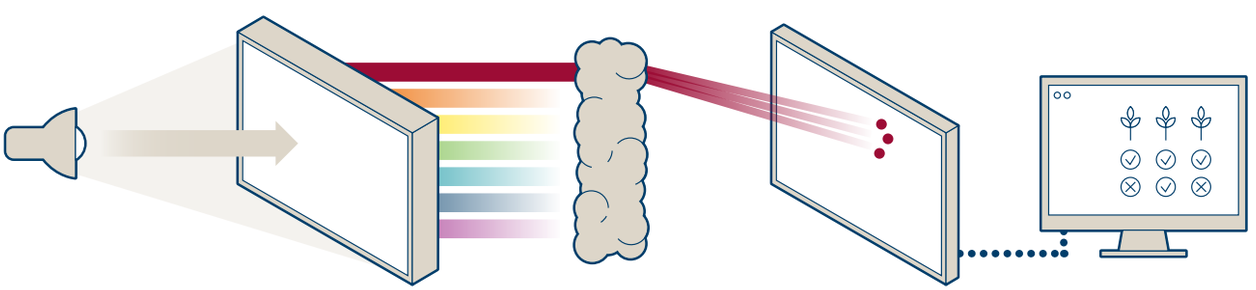
For many years, optimization was primarily based on economic considerations, as feed is by far the biggest cost factor in livestock farming, and proteinaceous raw materials are particularly expensive. Sustainability has increasingly played a role as well. "It has become clear that the crude protein content in the feed also determines its environmental footprint," says Emthaus. "This gives us an effective means of improving sustainability." Because the Rothkötter Group not only produces compound feed but also processes the chickens it feeds into meat products, it can also reap rewards with retailers and environmentally conscious end consumers.

A publication by the German animal nutrition association Deutscher Verband Tiernahrung (DVT) from 2022 shows that the use of amino acids is effective. According to the article, the crude protein content in chicken feed from the five leading producers in Germany fell from an average of 20.8 percent in 2000 to 19.3 percent in 2020. This corresponds to a relative change of seven percent. At the same time, the animals reach a higher weight. If the crude protein content is related to the live weight of the chickens, the amount of protein used has actually decreased by 18 percent.

Another benefit is that less ammonia is produced if farm animals excrete less unused protein and therefore less nitrogen. Ammonia is a nitrogen compound that is problematic in several respects: If it reacts with certain air pollutants, it can produce particulate matter that is hazardous to health. In water and soil, ammonia can lead to eutrophication and acidification.

WHAT IS IN SOYBEANS, WHEAT OR RAPESEED?

How near-infrared (NIR) spectroscopy can be used to analyze the composition and quality of raw feed materials



Light source

In the NIR spectrometer, a monochromator splits white light into the color spectrum of the rainbow.

Monochromator (grating)

Sample

Beyond red is the invisible near-infrared, which hits the feed sample. This stimulates the molecules in the sample to vibrate.

Detector

The proportion of diffusely reflected light is recorded by a detector and provides information about the molecular composition of the sample.

Analysis

The spectroscopic data is analyzed using mathematical models (NIR calibrations) and the measurement results are compared with reference data.

The measured NIR spectra are transmitted online to Evonik and analyzed there

“In animal feed, it’s the amino acid composition that counts”

MAIKE NAATJES, AGRICULTURAL ENGINEER AT THE EVONIK BUSINESS LINE ANIMAL NUTRITION

The EU has therefore limited the permitted level of ammonia emissions. In Germany, for example, emissions will be limited to 431,000 metric tons per year from 2030. A protein-reduced diet helps to achieve this goal. According to the DVT, the calculated nitrogen emissions per kilogram of chicken in Germany fell by more than a third between 2000 and 2020, from 31 grams to 20 grams.

The animals also benefit from the adjusted diet, as Emthaus explains: “They excrete less unused protein. Moreover, chicken manure contains less water because nitrogen emissions and water consumption are linked. The animals are drier in the barns, which reduces the risk of bacterial infections.”

PROTEIN FROM LOCAL SOURCES

When it comes to making animal feed more sustainable, Rothkötter also relies on local raw materials, whose quality is also carefully analyzed. By-products from local food production are particularly attractive. These include shell residues that are produced when milling grains such as wheat. “The products we use for animal feed can be consumed by humans to only a limited extent or not at all. However, the resulting meat contains high-quality protein for human consumption,” says Emthaus. Oil extraction from rapeseed or sunflowers also produces by-products that can be used as animal feed. Rothkötter’s purchasing/recipe design team monitors raw material exchanges to track exactly which components are available when. It also receives offers via direct contacts with food producers. If the raw material base of the feed changes, the overall mixture must be reformulated. Rothkötter usually does this once a week.

The feed for broiler chickens and pigs consists of five to 15 main components and a number of smaller ingredients. Changes should be kept to a minimum so that the animals do not have any problems with the change in feed. Nowadays, software helps to adjust feed mixes. This allows feed to be optimized in terms of quality, sustainability, and cost-effectiveness.

Soybean meal is an indispensable raw material, as it has the most favorable amino acid composition of all plant components for animal feed. Just like rapeseed meal, it is a by-product of oil production. Rothkötter Mischfutterwerk sources it from South America and Europe.

In order to make soybeans suitable for consumption by animals and humans, they are first heated by oilseed processors. This is necessary to deactivate certain substances in the legume. However, excessive heat →

Christian Emthaus from Rothkötter and Evonik expert Maike Naatjes in the feed mill during the production of chicken feed

destroys heat-sensitive amino acids in soybeans. This heat treatment, known as toasting, is a balancing act that doesn't always work perfectly, but has a very significant impact on the digestibility of the soybean meal and therefore its quality as animal feed.

Evonik scientists have developed a patented process that uses NIR analysis to determine how well soybean meal can be digested. This enables Rothkötter to make the raw material more usable with the help of added amino acids.

Like all other ingredients, the meal is transported in the most environmentally friendly way possible—for example by freighter to Rotterdam and then by barge, rail or truck to the plant. When it comes to the environmental footprint of a plant-based raw material, the efficient use of land also plays a decisive role. It depends on factors such as soil conditions, weather conditions, and size. This means that certified soybean meal from South America, where two harvests per season are possible, can perform just as well as European soybean meal in the overall assessment.

In addition to analytics, life cycle assessments are an important driver of feed optimization. TÜV Rheinland has certified a life cycle assessment that Evonik conducted in 2021, which shows that the greenhouse effect of livestock farming in Europe could be reduced by nine to 14 percent and overfertilization by nine to twelve percent simply by supplying broiler chickens, laying hens, and pigs with low-protein feed and adding free amino acids. In addition, the amount of arable land used could be reduced by up to 13 percent. Rothkötter and Evonik show how it's done.

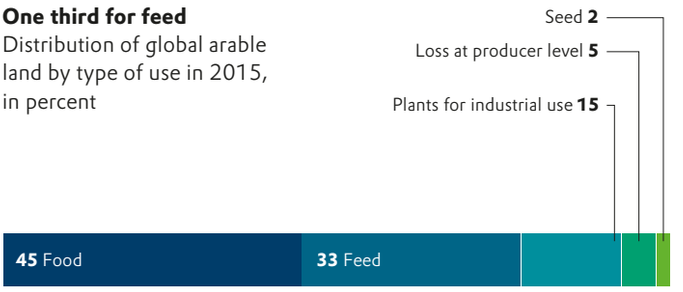
Annette Locher has a degree in biology. She has been working for Evonik since 2012. She writes primarily about health, nutrition, and sustainability

OFF TO THE TROUGH

A large proportion of the world's agricultural production is fed to animals. In order to meet the growing demand for protein, the animal feed industry is tapping into new sources and switching to sustainably produced raw materials. A numerical overview

INFOGRAPHIC **MAXIMILIAN NERTINGER**

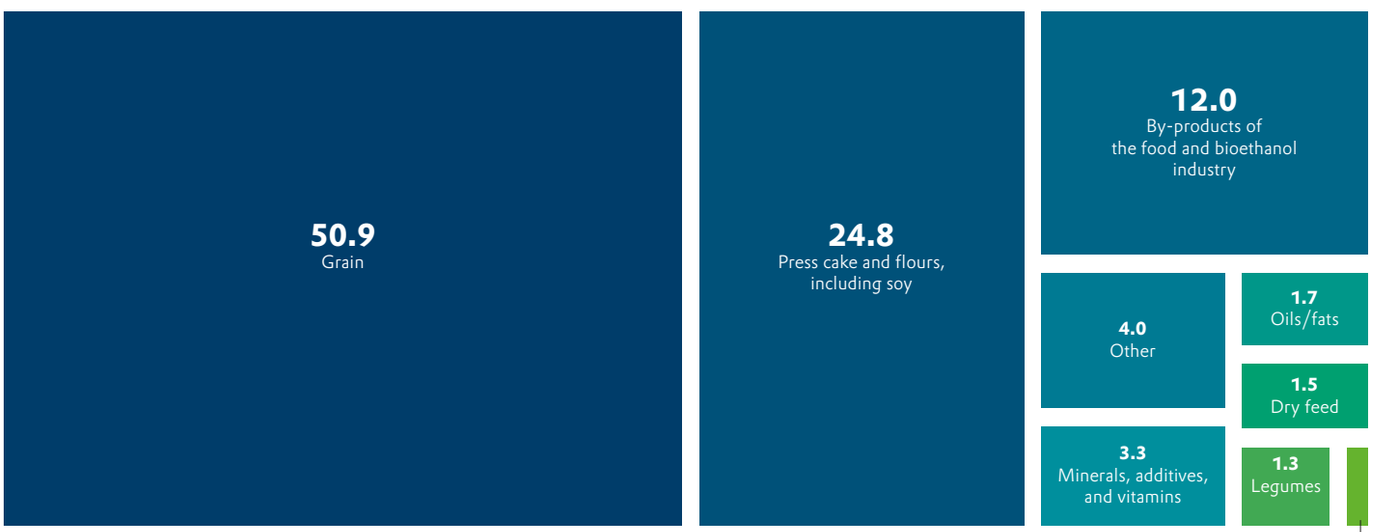
One third for feed
Distribution of global arable land by type of use in 2015, in percent



Source: FAO

Total: **48.6 million square kilometers**

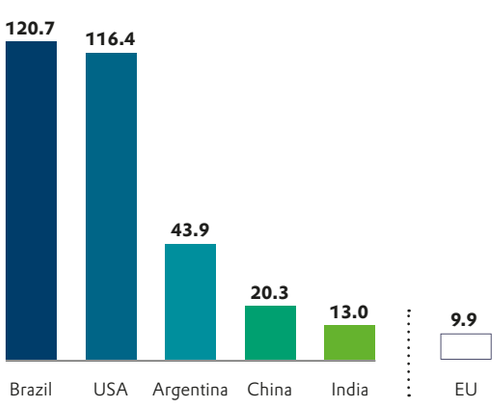
Grain as a main course
Source materials for feed production in the EU in 2022, in percent



Source: FEFAC

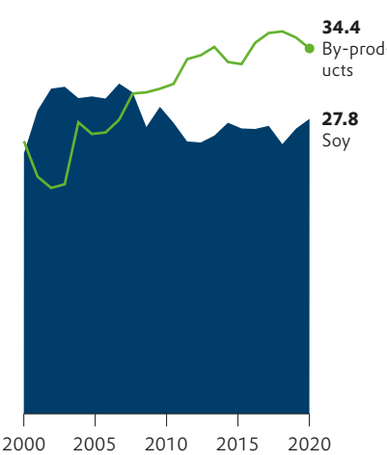
Total: **147.3 million metric tons**

Hardly any soybeans from Europe
The biggest soybean producers in 2022, in millions of metric tons



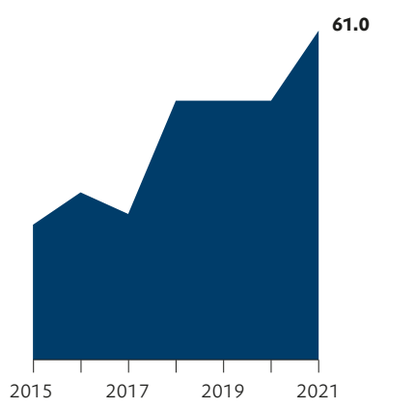
Source: FAO

Rise of new sources of protein
Processing volumes in the EU feed sector in 2022, in millions of metric tons



Source: FEFAC

Growing awareness
Share of sustainably produced soybeans in EU compound feed production in 2021, in percent



Source: FEFAC

JAPAN: ROOTS AND RESILIENCE

Japan is a highly developed industrial nation. But elements of the country's rich cultural heritage are firmly anchored even in the midst of its bustling major cities. Whether it's comics, cuisine or stagecraft, this island nation on the rim of the Pacific Ocean knows how to integrate tradition into modern life

TEXT **PAULINE BRENKE**

Mount Fuji rises majestically above the city of Fujiyoshida in Japan, forming a picturesque motif in combination with the five-story Chureito Pagoda and pink cherry blossoms. This volcano is a key element of Japanese culture and holds spiritual significance for many natives of Japan. With a height of 3,776 meters, Fuji is Japan's tallest mountain. On clear days it can even be seen, at a distance of 200 kilometers, from Japan's capital Tokyo.

In Japan, the electrification of vehicles was for a long time practically synonymous with hybrid drive systems. But in the past few years the importance of purely battery-powered vehicles has increased considerably in Japan, and the construction of charging stations is subsidized by the government. Evonik would like to strengthen Asia's growing market for new battery generations in electric vehicles. To this end, it is expanding a production plant for AEROXIDE®, an aluminum oxide that is used in lithium-ion batteries, in the city of Yokkaichi. This product makes it possible to extend the range of electric vehicles and provides greater safety as well as shorter charging times for the batteries.

Girlish comic figures with huge eyes gaze down at the pedestrians strolling through the Akihabara district of Tokyo, which has developed into a hotspot for fans of anime and manga. Dozens of shops and cafés have specialized in the lively comics, animated films, and heroic figures of these genres. In the West, "manga" is an umbrella term for the typical style of Japanese comics, but in Japan itself the term usually refers to comics in general. The comics are typically drawn in black-and-white. Evonik supplies high-quality additives for printed products with high resolution and sharpness.

Painted faces, elaborate costumes, and exaggerated facial expressions and gestures—at a kabuki performance, the spectators are treated to an opulent show. Kabuki is a traditional type of theater whose roots go back to the 17th century. It has been on the UNESCO list of Intangible Cultural Heritage since 2005. The actors' makeup, which is known as *kumadori*, plays a crucial role: The colors and lines provide information about a character's gender, social status, and personality. Evonik produces specialty silicas for decorative cosmetics. Besides improving the structure and stability of cosmetics, these products also replace microplastics.

Contrary to popular belief, sashimi is not sushi—it's an independent dish. It usually consists of finely sliced fish filets that are served with soy sauce, wasabi, and small decorative side dishes. Unlike sushi, it is not eaten with rice! Top-quality fish is essential for good sashimi. In order to conserve wild fish stocks, which are a limited resource, Evonik has developed a sustainable technology that replaces animal-based ingredients in fish feed. The joint venture Veramaris produces omega-3 fatty acids using natural marine algae instead of fish oil or fish meal.

The word *"dekotora"* is a shortened form of *"dekoreshon torakku"*, or "decorated truck". In Japan, trucks are beautified with textiles, painting, neon lights, and unusual extensions, from the driver's cab to the body. The *dekotora* culture reached its high point in the 1980s and 1990s. Today only a few of these super-decorated trucks roll along Japan's highways—partly because of stringent regulations governing decorations. However, *dekotora* are still inviting spectators to admire their mobile artworks at public events, usually for charitable causes. Evonik helps to make "green tires" for cars in order to save on fuel and increase safety thanks to shorter braking distances. It has recently become possible to use the combination of ULTRASIL® silica and special rubber silanes in the production of truck tires as well.

Wada san and his truck "Uta Maru" in Aichi prefecture, Japan. This photograph comes from Julie Glassberg's long term documentary project "Dekotora". Julie started to document the Dekotora culture in 2015 as she was living in Japan for a year. In 2019 and 2023, she went back to Japan to prepare a book with the editions Patrick Frey

The red Wakato Bridge, which is 627 meters long, connects the wards of Wakamatsu and Tobata on Kyushu, Japan's third-largest island. Visitors to Kyushu like to bathe in its hot springs, climb its volcanoes, and eat the famous local specialty, ***tonkotsu*** ramen. Specialist circles call Kyushu "Silicon Island". Its Kumamoto Prefecture in particular is an important location for semiconductor production in Japan, and new investments here are intended to revitalize the sector. Kyushu's abundant water resources are a great advantage for the production of semiconductors. Evonik produces colloidal silicas as an abrasive for silicon wafers—an important step in the production of microchips.

IN THE MIDST OF THINGS

Greater Tokyo, which has more than 37 million inhabitants, is the biggest urban agglomeration in the world, as well as the economic, political, and cultural center of Japan. Evonik has been active here since 1969. Evonik's headquarters in Japan are in the Shinjuku special ward, a renowned entertainment and shopping district. Eight other locations are distributed around the metropolitan area and further south on the island.

Evonik location

1 Tokyo, Shinjuku-ku
2 Ibaraki, Inashiki-Gun
3 Kanagawa, Kawasaki-shi
4 Kanagawa, Isehara-shi
5 Aichi, Nagoya-shi
6 Mie, Yokkaichi-shi
7 Kyoto, Kyoto-shi
8 Hyogo, Himeji-shi
9 Hyogo, Ako-shi

At

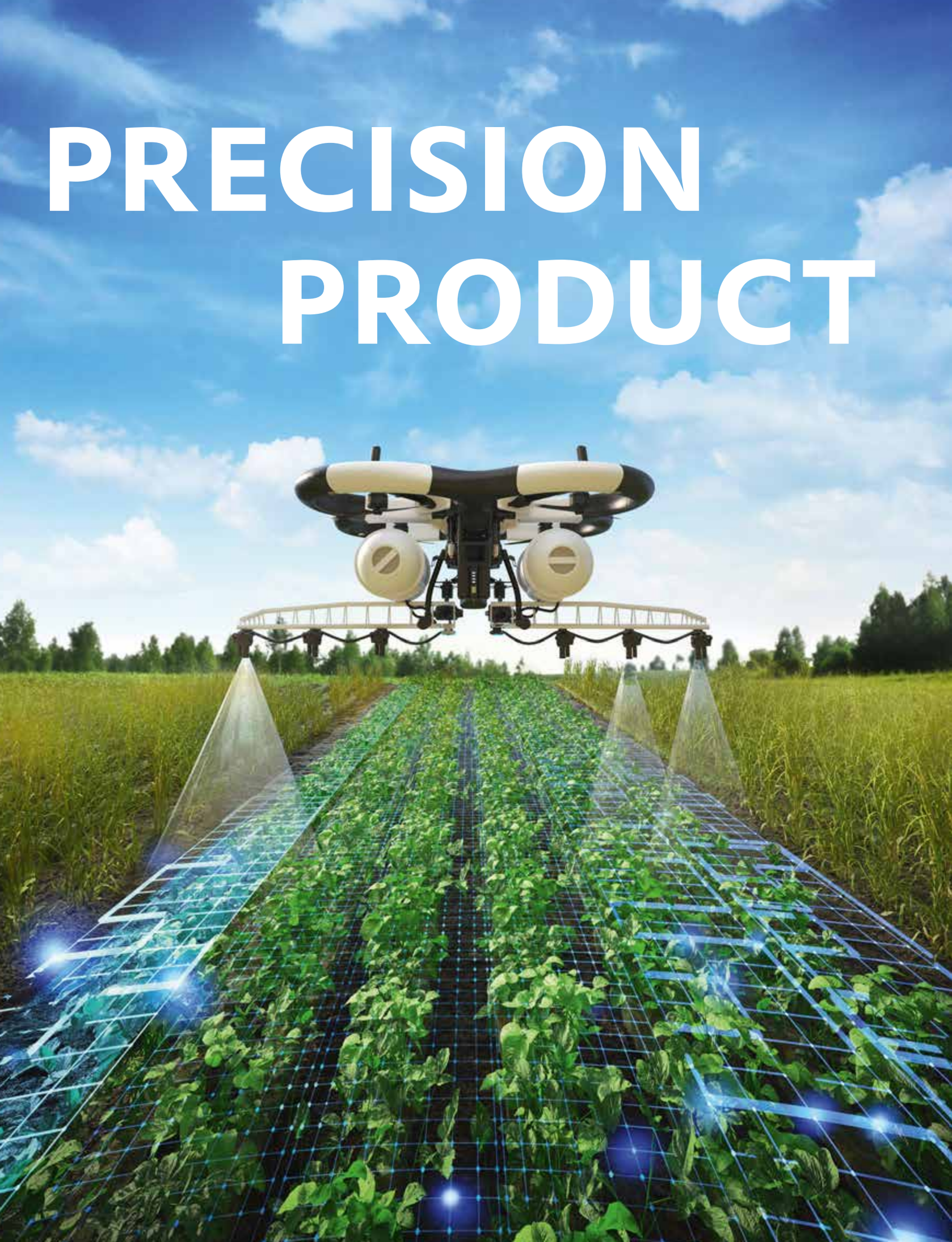
9

locations, Evonik has

468

employees.

PRECISION PRODUCT



Leaves are normally water-repellent so that rain and dew roll off. Adjuvants cause water droplets to cling to the leaf (right)

In many parts of the world, crop protection agents will be spread by drones in the future. The new technology places special demands on the spray mixture. Evonik has found a formulation that prevents unwanted drift and distributes the active ingredients as well as possible on leaves

TEXT **TIM SCHRÖDER**

Although thrips are just one millimeter long, farmers fear the tiny creatures because they can cause great damage, especially in subtropical and tropical regions. The insects with the characteristic fringed hairs on the edges of their wings eat the leaves and flowers of many useful plants, such as cotton, tomatoes, and tea. They also transmit viruses that kill many plants. This makes thrips one of the most dangerous plant pests—including in India, where, according to the country's Tea Research Association, around 150,000 tons of tea are lost every year due to infestation by thrips and their caterpillars. That's around 15 percent of the entire harvest.

Farmers have been using sprays for decades to keep crop pests at bay. In industrialized nations, these are usually sprayed using tractors, while in developing countries and emerging markets they are often applied by workers who carry the spray mixture in tanks on their backs. However, drones are very likely to be buzzing over Indian fields and farmland more frequently in the future. Flying low, they will spray crop protection agents to combat insect pests and pathogens.

CARRYING 100 KILOGRAMS ACROSS FIELDS

Just a few weeks ago, the Indian Ministry of Agriculture was one of the first in the world to give the green light for the use of drones in agriculture. In a standard operating procedure (SOP), the ministry specifies how the UAVs are to be used. Drones are now also a major agricultural topic in other countries such as China and Brazil. The necessary technology already exists. In recent years, models that can carry weights of 100 kilograms and more have come onto the market, particularly in China, but also in Germany and the USA. According to a recent industry study, the market for agricultural drones could grow to an annual volume of more than nine billion US dollars by 2028—three and a half times as much as in 2022.

The use of drones requires manufacturers of agricultural chemicals to adapt their products to the new technology. If crop protection agents are sprayed in flight, the droplets can be blown further away (drift) by the wind than if they are sprayed by tractors or hand sprayers. To prevent this from happening, the agents →

A camera is used in the laboratory to examine how drops land on a film and how they behave on it. Ideally, they stick and spread

need to contain chemical additives. Evonik is at the forefront of the development of these specialty chemicals. “This topic fits very well into our strategic innovation portfolio and is driving the development of our product portfolio in the agricultural sector,” says Dr. Nina Hoppe, who heads the research and development department for the Interface & Performance business line at Evonik in Essen.

The advantages of aerial spraying are obvious: Drones spray fields up to seven times faster than tractors and can also be used in areas of softened soil and on steep and impassable terrain. They can also be equipped with cameras to detect where pests or diseases first appear and then apply targeted protective agents. In addition, the energy consumption and CO_2 emissions of the generally electrically powered UAVs are significantly lower than those of diesel tractors.

In the run-up to the large-scale use of drones in India, the ministry has issued a directive that obliges farmers and drone pilots to prevent crop protection agents from drifting. “In many areas of India, the plots are quite small. Moreover, farmers often grow different crops and fruits on adjacent fields,” says Sachin Vishwakarma, an expert in applied agricultural technology at Evonik, who is based in the western Indian city of Thane.

CONTROL OF INSECT PESTS

Vishwakarma is a member of an Evonik team that has been working in recent years to eliminate the drift of crop protection agents. This is accomplished by adding substances to the spray mixture that cause the droplets to fall to the ground or onto the plants before the wind carries them away. The development of these additives and auxiliaries, which are known as adjuvants, took several years. Last winter, Vishwakarma and his Indian colleagues tested the agents in the field for the first time. His conclusion was: “The results are convincing. We see no discoloration, burns or other damage on crop. On the contrary, it effectively controls insect pests such as thrips.”

From a chemical point of view, the development of adjuvants is a fine art because they have to have very different effects when sprayed. Firstly, the droplets that are released from the spray nozzle should fall quickly to the ground so that the wind doesn’t carry them away. Secondly, they should adhere to leaves and not roll off like rain. Otherwise the protective effect would be lost. Thirdly, the drops should wet the leaves as well as possible so that the active ingredient can penetrate them over a large area. As a result, the spray agent must not remain on a leaf in the form of spherical drops. Rather, the drops should cling to the leaf and spread out on it.

In order to fulfill all these functions, several ingredients with precisely coordinated properties have to be combined in an adjuvant.

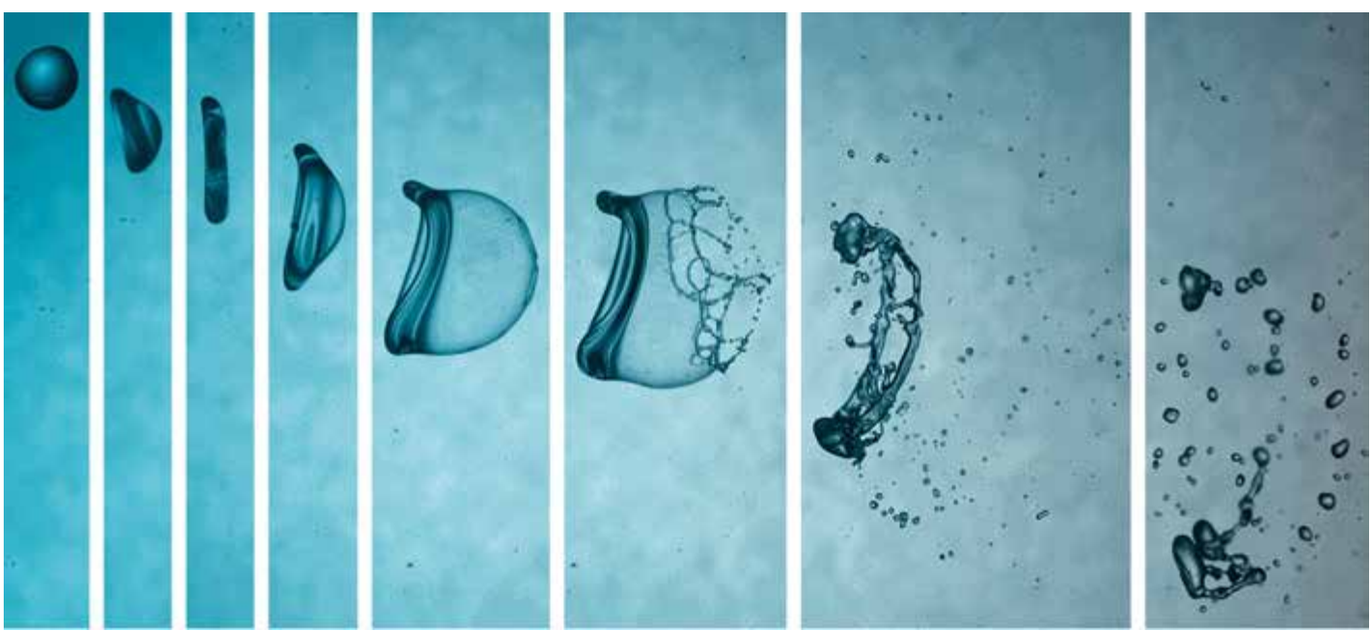
To accomplish this, the team from Evonik developed the adjuvant BREAK-THRU® MSO MAX 522. Trisiloxanes—compounds of silicon, oxygen, and carbon which Evonik has been producing for many years—are one important ingredient. They are used in many different ways in industry—for example in polyurethane foams or paints and varnishes as well as in many technical applications.

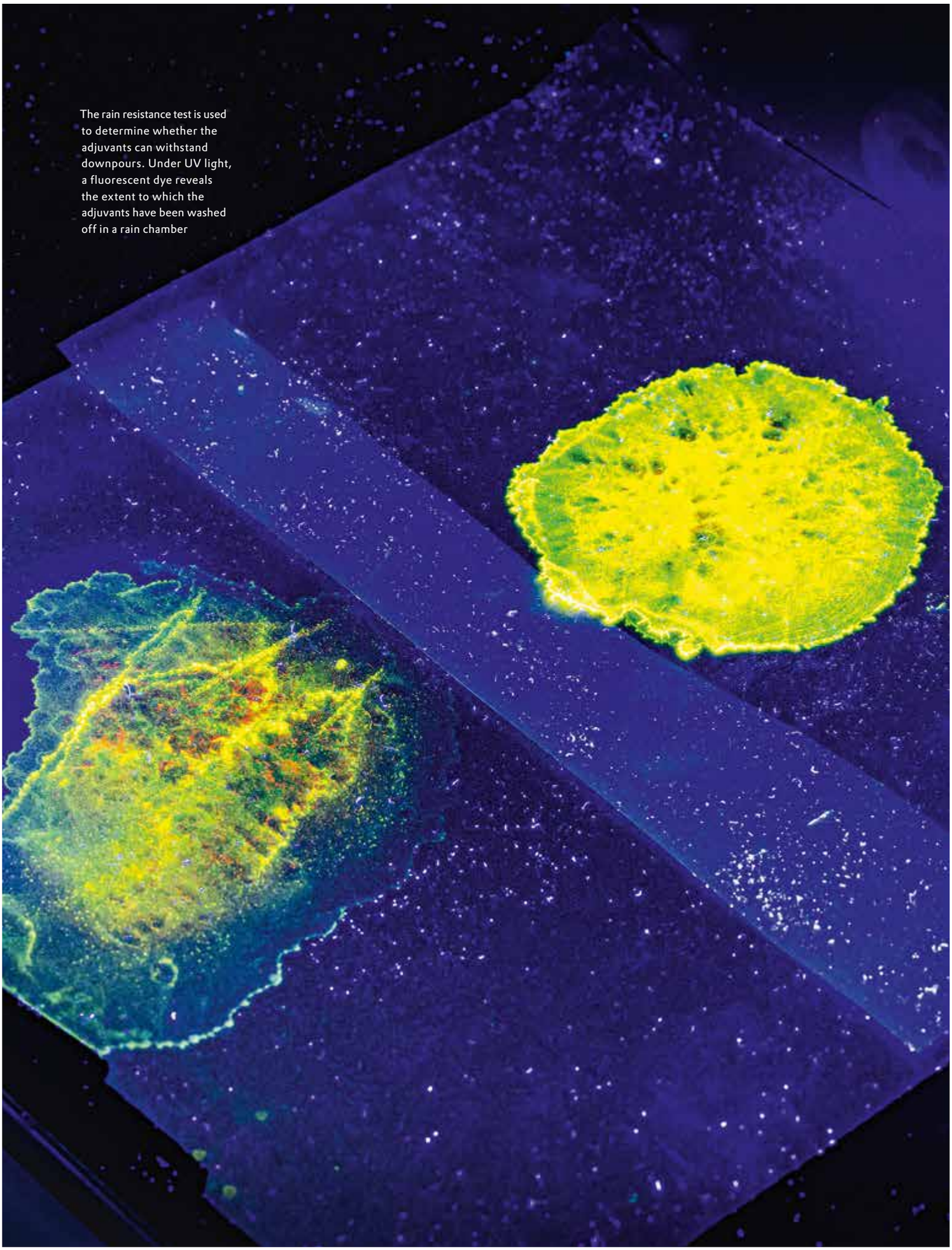
When used in the field, the adjuvant should deliver the spray agent as precisely as possible to the target. "Drifting also occurs when tractors are used," says Dr. Joachim Venzmer, an expert in interfacial technologies at Evonik in Essen. "But the problem is exacerbated when you use drones." To reduce this effect, plant-based thickeners can be added to the spray mixture, usually guar gum obtained from the guar bean. This means that only large droplets are produced when spraying, which fall directly to the ground or onto the plants. The disadvantage is that the thickened liquid can no longer →

The physical chemist Dr. Joachim Venzmer has studied the physical principles of droplet formation in detail in order to prevent spray agents from drifting

UNDERSTANDING WATER DROPLETS

In the wind tunnel, you can observe how water droplets emerge from a spray nozzle. They first bulge out to form a pocket until they finally rupture and form many small spray droplets. The earlier the pocket ruptures, the larger and heavier the droplets are, and the less widely they spread in the surrounding area.





The rain resistance test is used to determine whether the adjuvants can withstand downpours. Under UV light, a fluorescent dye reveals the extent to which the adjuvants have been washed off in a rain chamber

“The adjuvants will be a blockbuster in India”

SACHIN VISHWAKARMA, EXPERT IN APPLIED AGRICULTURAL TECHNOLOGY AT EVONIK

be sprayed well. The spray cone becomes narrower and therefore only wets a narrow strip of field. A guar rubber solution would be completely unsuitable for drone use. The device would have to make very many flights over a field to spray it completely. Venzmer has therefore addressed the drift problem differently, for which he reached deep into his physical bag of tricks.

FROM POCKET TO WATER DROPLET

“As chemists, we initially didn’t understand the physics of spraying and atomizing at all” he says. He came closer to the solution when a doctoral student at the Technical University of Darmstadt investigated the atomization of jet fuel in a nozzle a few years ago. The researcher wanted to answer the question of how and when a liquid film ruptures and splits into fine droplets. “I stumbled across this doctoral student by chance,” says Venzmer. This [TS1] proved to be a lucky encounter. Joachim Venzmer asked him to use the experimental setup, a small wind tunnel with a high-speed camera, to investigate how a film of water ruptures at a nozzle. A model experiment showed that a droplet in the air stream first bulges out into a pocket before it breaks. If it ruptures early, this is good, because then larger drops are formed. If, on the other hand, the pocket expands greatly before it ruptures, very fine droplets of spray are produced which are easily carried away by the wind.

The goal was thus clear: The aim was to control the rupture of the water film after it emerges from a nozzle in such a way that, firstly, droplet formation is not hindered and, secondly, the resulting droplets aren’t too small. This meant that the pocket shouldn’t rupture too late. Fortunately, one of the trisiloxanes already performed this task quite well. But it wasn’t yet enough for the drones. The team had to continue working on the right mix of ingredients.

“This better understanding of the physics of droplet formation has brought us the decisive step forward in the development of the adjuvant,” says Dr. Annika Dietrich, a chemist in Evonik’s Applied Agricultural Technologies unit. The challenge ultimately lies in the fact that a spray agent has to fulfill so many different functions: from droplet formation to spreading on the leaf. “When formulating, we therefore always look for ingredients that ideally fulfill several functions,” says Dietrich. Dietrich and her superior, René Hänsel, have found such a multifunctional substance in the vegetable oil contained in BREAK-THRU® MSO MAX 522: The oil not only causes the spray film to rupture earlier, so that sufficiently large drops are produced, it also ensures that the leaves absorb the active ingredient very well. Another benefit is that the oil forms a particularly water-resistant film once it has dried. This means that the active ingredient adheres firmly to a leaf for many days and is barely washed off by rain. →

Annika Dietrich has found a formulation that ensures that the spray mixture lands precisely on the leaves and is well absorbed by them

Research in a box: Laboratory technician Volker Klotzbach prepares a box to sprinkle water on plastic films coated with adjuvants

IS IT STILL DRIZZLING OR IS IT ALREADY RAINING?

In order to optimize this effect, the research teams in Essen and Marl carry out numerous "rain resistance tests"—in simple plastic boxes from the furniture store. For this purpose, the adjuvant is applied to films whose water-repellent properties are similar to those of a leaf surface. To determine how well different adjuvant formulations adhere, they are mixed with a dye that fluoresces under UV light. For the test, the film is sprinkled with water, dried, and then placed under a UV lamp. Depending on how much adjuvant—and therefore also dye—was washed off, the area on which the sample was applied fluoresces more or less strongly,

The team has already developed many variants, reports Nina Hoppe, who coordinates and manages the project: "For example, we are seeing increasing interest from our customers in biodegradable adjuvants made from renewable raw materials. We have therefore developed a formulation that does not require trisiloxane."

Instead, a polyglycerol ester is used, a substance made from plant-based raw materials, which is also an important component of cosmetics. It has good anti-drift properties, spreads very well on the leaf, and is also rainproof. The adjuvant has now been launched on the market under the name BREAK-THRU® SP133. "For our customers, we keep an eye on the regulations in the various agricultural markets worldwide to ensure that the product meets all requirements," says Hoppe. To prevent the spray agent from drifting, for example, many countries stipulate that droplets must have a diameter of at least 135 micrometers. The new adjuvants easily achieve this value.

USED FROM CHINA TO BRAZIL

The market could develop rapidly in the coming years. "We are currently seeing strong interest in drones, especially in India, China, and other Southeast Asian countries," says Diego Abreu, Head of Marketing at the Interfaces and Performance unit in Evonik's Agriculture segment. Drones that hit their targets with pinpoint accuracy with the help of the new adjuvants will be a key element of precision farming in the future.

High technology above fields: In India, drones are to be increasingly used in cotton fields in the future, not least to reduce the amount of water used for spraying

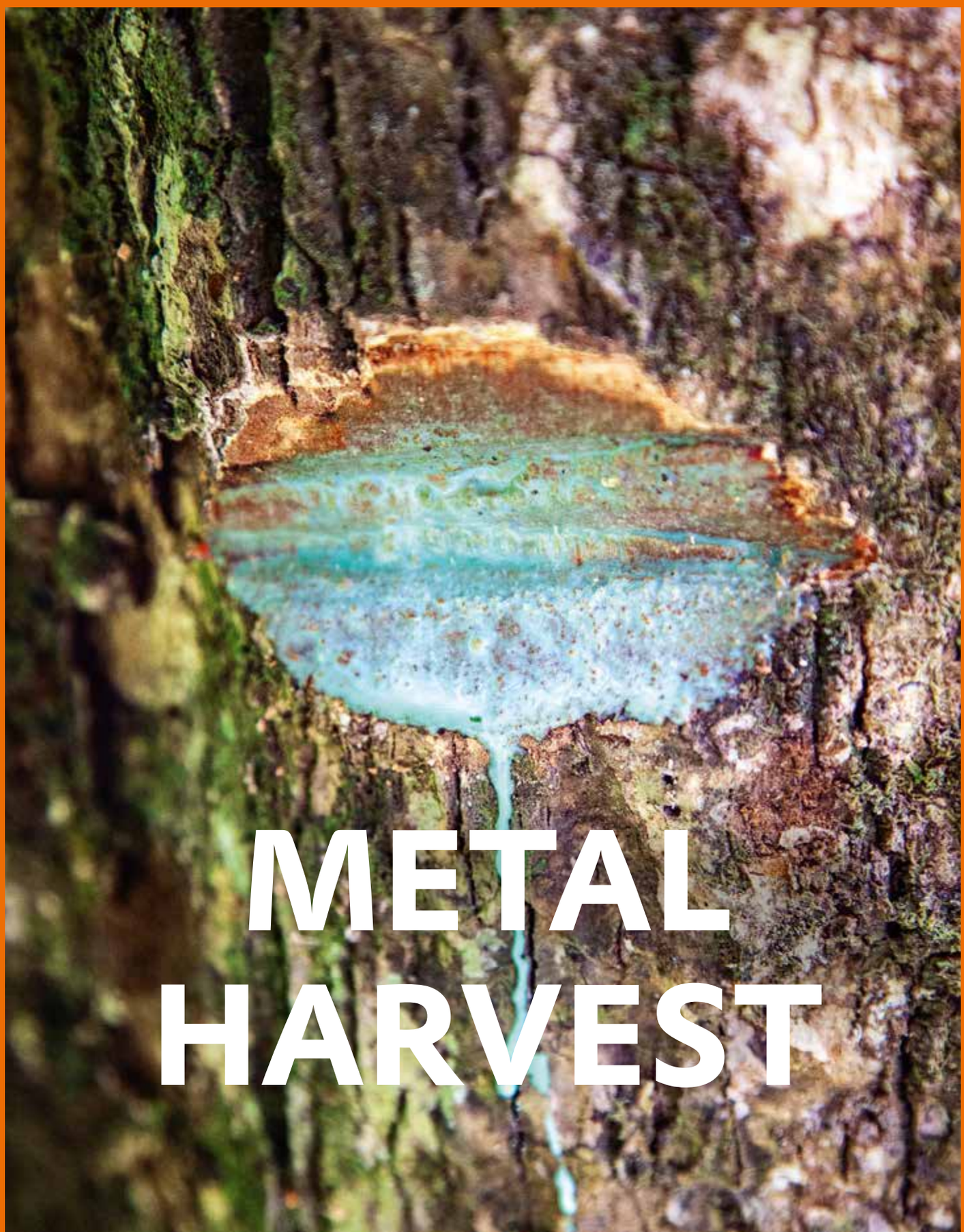
"The business models for which the drones are used can vary widely," says Abreu. In less developed countries in particular, few farmers can afford an aircraft, which can easily cost several tens of thousands of euros. "In China, for example, drone spraying are being mostly offered by the agricultural retailers that also sell the crop protection agents," he adds.

Abreu expects that Brazil and other Latin American countries will also have significant drone markets soon. In Europe, on the other hand, tractors will probably continue to be used in the coming years because the authorities are rather hesitant when it comes to approving aerial application technologies for pesticides.

One of the advantages of UAVs is that they significantly reduce water consumption. This is a great advantage, especially in dry regions. Drones can't carry as much water as a tractor. Therefore, special formulations must be used in drones, where 10 to 40 liters of water are already sufficient to apply the same amount of pesticide per hectare as 200 to 1,000 liters of water for conventional sprays. In addition to new formulation technologies, this approach mainly requires the new adjuvants. Among other things, these adjuvants ensure excellent wetting of the leaves and spreading.

As the first field test in India has shown, plants can cope very well with the high concentration of active ingredients and the added adjuvants. Further trials are planned for the coming months. Sachin Vishwakarma and his team will test the drone on other crops in order to perfectly adjust the mixture of spray liquid, adjuvants, and active ingredients. The official market launch for drone use is planned for 2025. In view of the advantages that the technology offers, Vishwakarma is already certain that "the adjuvants will be a blockbuster here."

Tim Schröder is a science journalist who lives in Oldenburg.



METAL HARVEST

The tree *Pycnandra acuminata* can concentrate large amounts of the heavy metal nickel. That's why the sap of these plants is turquoise in color

Many valuable raw materials cannot be extracted from the ground by means of traditional methods. However, plants could help us extract metals and rare earths in a new way. The age of agromining is dawning

TEXT **BJÖRN THEIS**

In March 2024 the Advanced Research Projects Agency-Energy (ARPA-E) announced an initiative of the US Department of Energy: a support program with US$10 million in funding. Its goal is to conduct research on plants that extract critically important materials from the soil. The program aims to strengthen local supply chains, improve America's economic and national security, and meet the growing demand for these materials. In the first step, the scientists will explore the plant-based extraction of nickel, an important raw material for the production of many industrial, medical, and consumer goods such as rechargeable batteries, implants, and glass.

MINING PLANTS

The concept of using plants to extract metals and rare earths dates back to the 1990s. That was when the English professor of botany Alan Baker and the American agronomist Rufus Chaney discovered plants that were thriving spectacularly in soil that was severely contaminated with heavy metals. They discovered that these "hyperaccumulators" can absorb metals and rare earths from the soil and store them in high concentrations. One example of that is *Pycnandra acuminata*, a tree which grows primarily in Borneo and New Caledonia. The tree's resin and cell sap, when dried, contain up to 25 percent nickel.

Nonetheless, the technology known as agromining or phytomining was never actually applied. For unknown reasons, the Viridian Environmental investment company, which financed Baker's and Chaney's research and held the related patents, prohibited the industrial use of these hyperaccumulators.

However, by the time the patents expired in 2015, the rising prices of raw materials and increasing geopolitical unrest sparked interest in this type of raw material production. Between 2016 and 2021, the EU project Life-Agromine, in which the Ruhr-Universität Bochum also participated, evaluated the use of phytomining for extracting nickel. The process turned out to be cost-efficient on a pilot scale: Up to 300 kilograms of nickel could be harvested per hectare of land. In terms of the raw material prices at that time, the profit yielded by this process was more than double that of maize cultivation. The process is already cost-efficient at a nickel concentration of 0.1 percent in the soil, whereas traditional mining requires a concentration that is at least ten times greater.

SOIL REMEDIATION

Hyperaccumulators can also remediate contaminated soils. About 20 percent of the soil in Germany is severely contaminated with heavy metals such as lead and cadmium. By using the right plants, these soils could be cleaned and made usable again.

The optimal hyperaccumulators for all metals have not yet been found, but the researchers are convinced that with the help of agromining a number of goals can be achieved simultaneously. Agromining can help to develop the sustainable and circular extraction of critical raw materials, minimize dependence on resources supplied by foreign countries, and reduce the price volatility of metals and rare earths. In addition, contaminated soils can be cleaned in a cost-effective and environmentally friendly process.

The Foresight team has dealt with the topic of agromining for a long time, and it is convinced that this technology can make an important contribution to the raw material extraction of the future. With suitable additives for fertilizing the hyperaccumulators and the right soil preparation, the plants' absorption capacity and the bioavailability of metals in the soil could be increased further.

Björn Theis heads the Foresight department at Evonik's innovation unit Creavis

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Pb
Lead

"Lead revolutionized book printing"

LOG **KAROLINA FÖST**
PHOTOGRAPHY **THOMAS PIROT**

Christoph Sünder is a master printer. He's the director of the workshop at the Druckladen, which is the department for educational programs at the Gutenberg Museum in Mainz. He regularly uses old type made of a lead alloy for his printing work

In the Gutenberg Museum in Mainz we've got more than a hundred cupboards full of old lead type from hundreds of different fonts. We bought them up or received them as gifts from printing companies that have gone out of business. We use this lead type to create unique products: certificates, texts, and cards for special occasions. Today hand-printed materials are regarded as art. Johannes Gutenberg did not want to create a work of art, even though that's how we think of the Gutenberg Bible today. Gutenberg, a native of Mainz, wanted to reproduce written documents faster and more flexibly than was usual back then. Before approximately 1450, when he invented book printing with movable type made of lead, books were copied out by hand or laboriously printed with woodcuts. The book "writers" were usually monks, and they needed about two years to complete a copy of the Bible. Thanks to Gutenberg, book production became much faster and cheaper from then on. Lead revolutionized book printing, and over time it made education possible for all.

We can only speculate about why Gutenberg chose lead. No original type from his era has survived, nor has any written account been handed down. The issue was probably decided by the fact that lead is easy to work with. It's a heavy metal that is easily malleable and has a relatively low melting point of about 300 degrees Celsius. That means it can be melted over a flame.

When I talk about lead as a printer, I'm actually referring to an alloy of lead, tin, and antimony. This composite is very suitable for printing: It cools quickly but nonetheless remains stable. After all, the letters shouldn't contain any air bubbles or change their shape after cooling off.

In order to produce the type for hand printing, the liquid metal was poured into a hollow mold, and the individual letters and punctuation marks were placed together—back-to-front and upside down—on so-called galleys to form words, sentences, and entire texts. The result was a forme of type that could print any desired quantity. It was clamped into the printing press, inked, and printed on sheets of paper. This process was to hold sway for more than 500 years.

Masthead

PUBLISHER Evonik Industries AG | Matthias Ruch | Rellinghauser Straße 1–11 | 45128 Essen, Germany | **CONSULTING AND CONCEPT** Manfred Bissinger | **EDITOR IN CHIEF** Jörg Wagner (responsible for editorial content) | **MANAGING EDITORS** Inga Borg, Bernd Kaltwaßer | **TEXT EDITOR** Christian Baulig | **ONLINE EDITOR** Pauline Brenke | **PICTURE EDITING** Nadine Berger | **LAYOUT** Wiebke Schwarz (Art Direction), Pearl Elephant (Graphics) | **EDITORIAL ADDRESS** KNSKB Group | Holstenwall 6 | 20355 Hamburg, Germany | **TRANSLATION** TransForm GmbH, Cologne | **PRINTING** Linsen Druckcenter GmbH, Kleve | Questions about ELEMENTS Magazine: Tel. +49 201 177-3315 | e-mail: elements@evonik.com | **PICTURE CREDITS** Cover illustration: Tobias Wüstefeld / Die Illustratoren | p. 3 Kirsten Neumann / Evonik Industries AG | pp. 4–5 Enno Kaptiza, m.malinika — stock.adobe.com, Robert Eikelpoth | pp. 6–7 Getty Images | pp. 8–9 Artur — stock.adobe.com, private, Chengyue Li; illustration: KNSK GROUP GmbH | pp. 10–17 Illustration: Tobias Wüstefeld / Die Illustratoren; photography: Enno Kapitza (5), Robert Eikelpoth (6); illustration: Oriana Fenwick / Kombinatrotweiss on the basis of an original photograph by Stefan Eisenburger | pp. 18–19 Infographic: Max Nertinger | pp. 20–25: Thomas Bauer / AD Photography (2), Gene Glover (3) | pp. 26–33 Illustration: Tobias Wüstefeld / Die Illustratoren; photography: Robert Eikelpoth; illustration: Oriana Fenwick / Kombinatrotweiss on the basis of an original photograph by Karsten Bootmann; infographics: Maximilian Nertinger | pp. 34–43 Bisual Studio / stocksy.com, Getty Images (2), ddp/CAMERA PRESS/Tristan Gregory, Getty Images, Julie Glassberg/Redux/laif, Getty Images | pp. 44–52 Illustration: Tobias Wüstefeld / Die Illustratoren; photography: Evonik Industries AG (2), private, m.malinika — stock.adobe.com, Henning Ross (7); illustration: Oriana Fenwick / Kombinatrotweiss on the basis of an original photograph by Foto- und Bilderwerk | pp. 52–53 Antony van der Ent, Wageningen University, Netherlands & The University of Queensland, Australia; illustration: Oriana Fenwick / Kombinatrotweiss on the basis of an original photograph by Karsten Bootmann | p. 54 Thomas Pirot

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“I know of no pursuit in which…

…more real and important services can be rendered to any Country, than by improving its agriculture,” wrote George Washington in 1797 to John Sinclair, the president of the Scottish Board of Agriculture. As the first president of the United States, Washington was committed to fulfilling the needs of the young nation.

Sufficient and healthy nutrition requires efficient livestock farming and methods of cultivation. The digitalization of agriculture promotes an increasingly precise use of resources and conserves the natural environment. ELEMENTS shows how modern analytics and formulations are helping to safeguard the world’s food supplies and improve working conditions without neglecting sustainability.