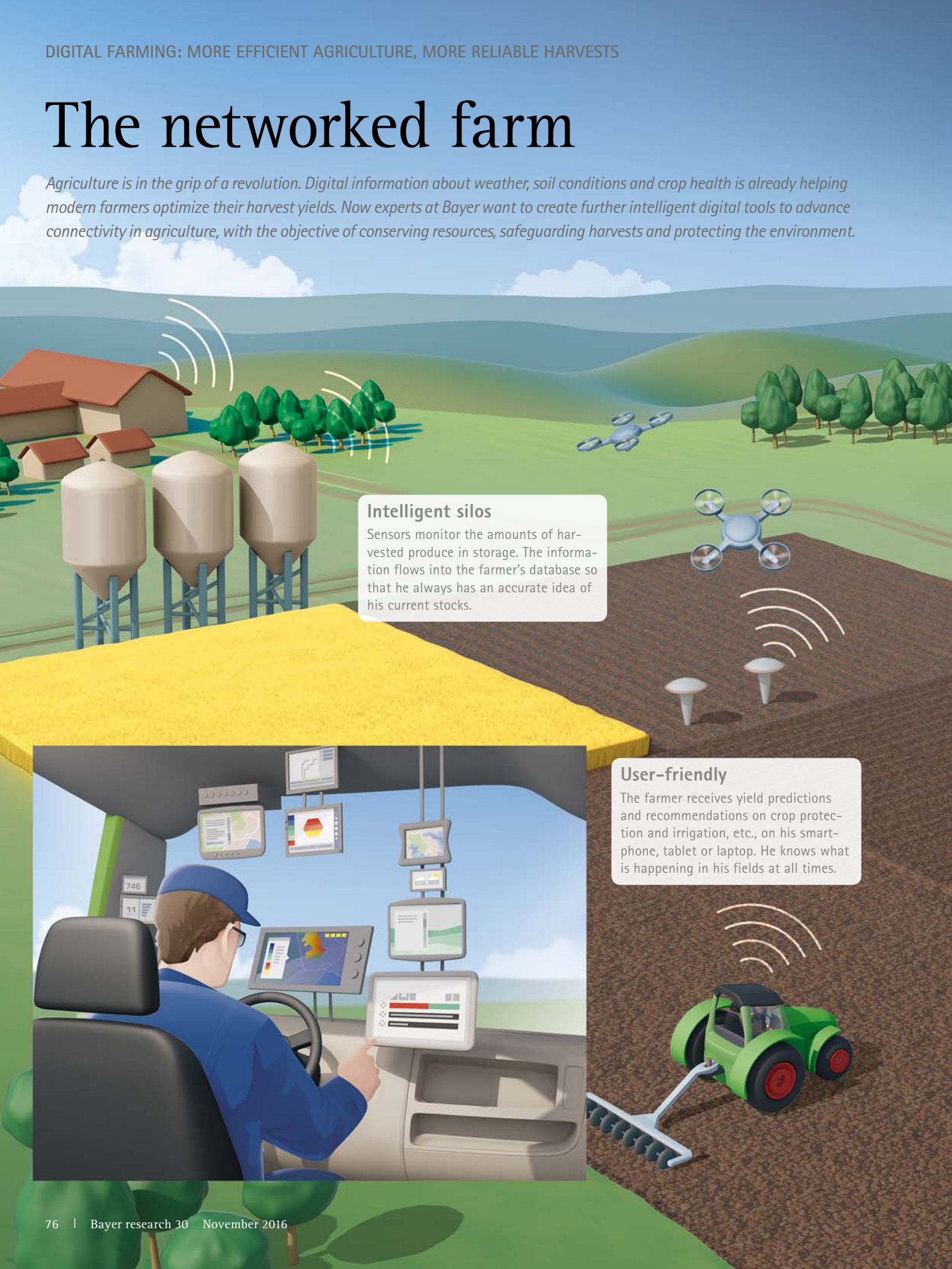
The networked farm

Agriculture is in the grip of a revolution. Digital information about weather, soil conditions and crop health is already helping modern farmers optimize their harvest yields. Now experts at Bayer want to create further intelligent digital tools to advance connectivity in agriculture, with the objective of conserving resources, safeguarding harvests and protecting the environment.

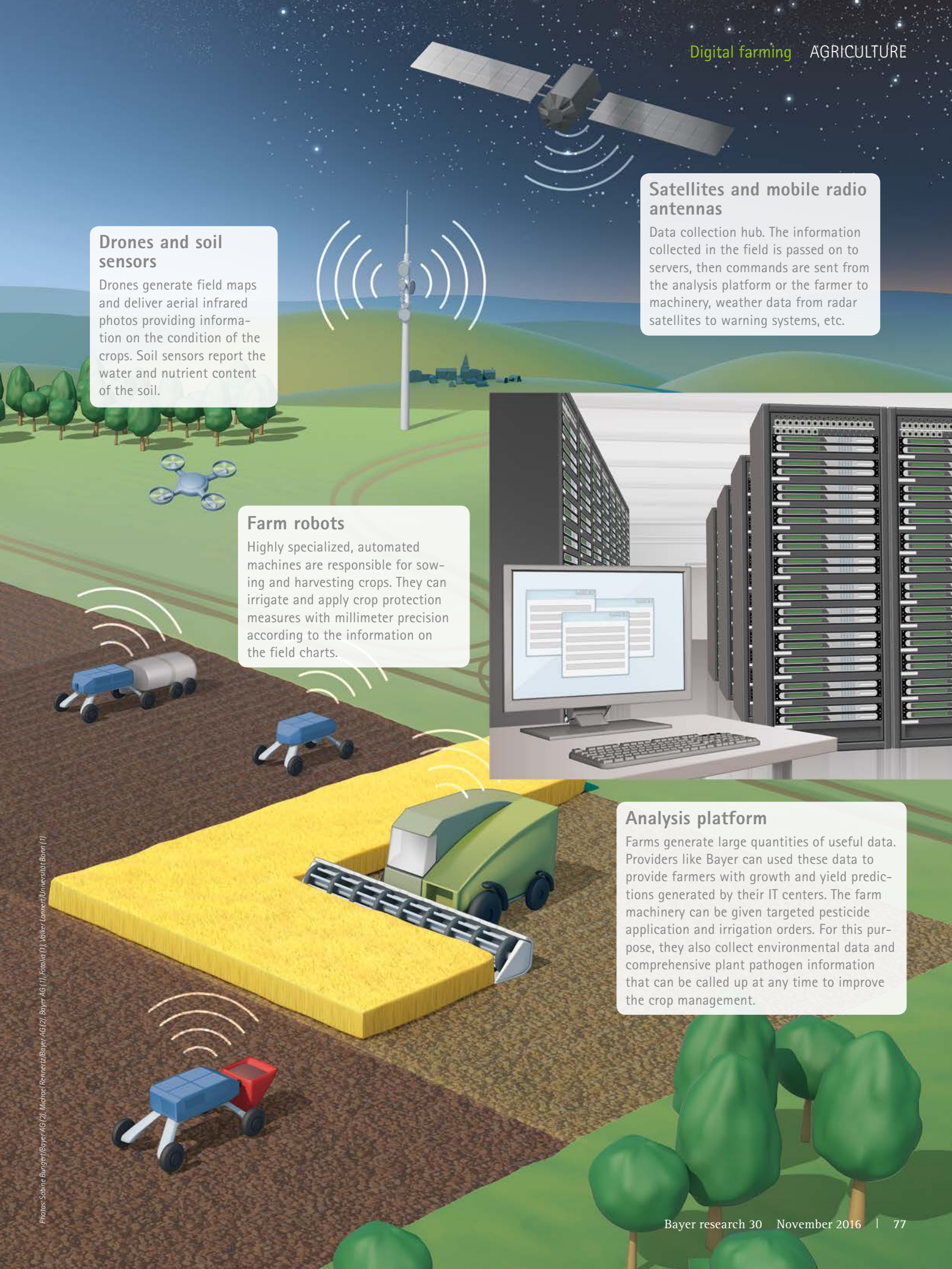


Intelligent silos

Sensors monitor the amounts of harvested produce in storage. The information flows into the farmer's database so that he always has an accurate idea of his current stocks.

User-friendly

The farmer receives yield predictions and recommendations on crop protection and irrigation, etc., on his smartphone, tablet or laptop. He knows what is happening in his fields at all times.



Satellites and mobile radio antennas

Data collection hub. The information collected in the field is passed on to servers, then commands are sent from the analysis platform or the farmer to machinery, weather data from radar satellites to warning systems, etc.

Drones and soil sensors

Drones generate field maps and deliver aerial infrared photos providing information on the condition of the crops. Soil sensors report the water and nutrient content of the soil.

Farm robots

Highly specialized, automated machines are responsible for sowing and harvesting crops. They can irrigate and apply crop protection measures with millimeter precision according to the information on the field charts.

Analysis platform

Farms generate large quantities of useful data. Providers like Bayer can used these data to provide farmers with growth and yield predictions generated by their IT centers. The farm machinery can be given targeted pesticide application and irrigation orders. For this purpose, they also collect environmental data and comprehensive plant pathogen information that can be called up at any time to improve the crop management.

Photos: Sabine Burger/Bayer AG (2), Meinrad Pennetzi/Bayer AG (2), Bayer AG (1), Fotolia (1), Volker Lannert/Universität Bonn (1)

Field analysis: a wealth of different information is sent to the tablets and smartphones of Tobias Menne (left) and Ole Peters. These weather data, measurements from sensors and information about soil conditions are collated and evaluated. The experts from Bayer's Crop Science Division are aiming to provide the ideal basis that farmers need to take decisions.

The digital revolution is changing the face of agriculture, with the zeros and ones that make up binary code set to become the most important tools for farmers worldwide. Highly automated tractors and combines equipped with a vast array of sensors are already traversing our fields of corn, oilseed rape, soybeans and wheat, collecting data about plant health, yields, soil composition and field topography. Drones and satellites are likewise helping farmers work more efficiently by generating millions of relevant data points. Nowadays satellite imaging allows us to analyze a single patch of land at a resolution of just 30 centimeters. The ability to analyze highly accurate data from the current growing season and compare it with previous years brings a whole new dimension to modern agriculture. "Farmers are able to better predict influences affecting yields and respond more quickly to changes. This means they can take prompt action to prevent harvest losses," explains Tobias Menne, head of Digital Farming at Bayer's Crop Science Division.

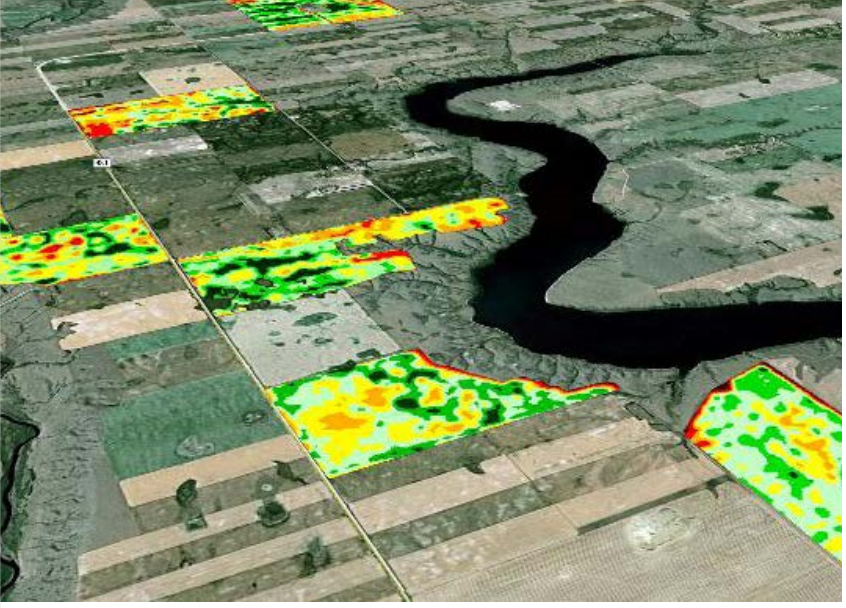
Higher yields thanks to sowing strategies matched to the soil

Digital farming is based on individual data elements. "There are thousands of different soil types around the world. But the soil's quality can vary greatly even within a region or a single field. The more a farmer knows about his soils, the better equipped he is to decide which varieties to sow in a certain area to produce optimal yields," says Menne. He and his team are eager to drive forward the digital revolution in agriculture.

Satellites survey crops in the fields from space

"Digitalization enables farmers to make rapid decisions tailored precisely to individual fields – from selecting the right crop variety and applying exactly the right fertilizer dose through to determining the ideal time for crop protection measures and recognizing plant stress factors at an early stage," Menne explains. The experts at Bayer can now use satellite data to remotely diagnose the condition of a crop and measure the biomass in each section of the field. But that's not all. "We can almost distinguish individual plants from space," says Menne.

Bayer's agronomists are also breaking new ground as they embrace the digital revolution. For example, they plan to collaborate with space technology company Planetary Resources in Redmond, Washington, USA, to develop new products. One possible example is a soil humidity index which provides information about the water storage capacity of the soil and issues automated recommendations for optimal fertilizer strategies



Keeping an overview: state-of-the-art sensor technology and measuring instruments provide high-resolution information which can be used to make maps (photo left) showing the condition and productivity of farmland. Drones (photo right) are also a useful tool for detailed field surveillance.

and the best time to irrigate. Another project could involve a canopy temperature monitor which provides daily information and recommendations for action during the time from when crops are sown through to the harvest by identifying problem areas in the field.

In 2015, Bayer acquired the Zoner geoinformation system from IntelMax in Calgary, Canada. Bayer researchers therefore now have new colleagues with extensive expertise in agricultural IT, as well as innovative software that can be used for the evaluation and graphic representation of the satellite images of selected agricultural areas in Canada, the United States, Brazil, France, Germany, Ukraine and Russia taken over a 30-year period. All this information is stored in a gigantic database which Bayer's agricultural experts now intend to harness to provide smart connectivity. They are currently working on the Agronomic Decision Engine – a management tool that will provide tomorrow's farmers with quick and simple answers to key questions, such as, is it worth using a crop protection product in this field? Which one? How much? When and where? What is the most suitable seed for my field? How often do I need to irrigate?

At the heart is the Bayer platform with data on the environment, plants and pests

Before Bayer's digital platform can provide answers to these questions, numerous parameters have to be fed into it. The researchers have deduced four key variables for analysis. "First we consider environmental factors: the soil condition, the exact temperature of the soil, the weather and the volume of water in the field," explains Dr. Ole Peters, Technical Director of the Digital Farming Team at Bayer. Equally important are any pathogens and other harmful factors such as fungi, insects, spiders, worms, weeds and other pests. The third variable of interest to the researchers is all the data about the crops and how they are affected by the first two variables – and they need to know everything, from how a particular plant responds to pathogens to the water requirements of oilseed rape or soybeans, for instance. Continues Peters, "We then factor in the management system: for example, the crop protection agents used, and how the farmer manages his soil." The Bayer researchers

Greater yields thanks to infrared

In 2014 several farmers in the USA participated in a study to compare new varieties of soybeans with existing ones. The trial fields were analyzed with a multispectral sensor mounted on an unmanned aerial vehicle. The infrared images produced by the sensor showed which areas of the field needed more attention. With the aid of near-infrared radiation, the experts at Bayer discovered stress factors that are harmful to plants long before they were visible to the human eye. This is because the infrared images reveal a wealth of information about the condition of the crops, such as their chlorophyll content – an indicator of their overall vitality. Since healthy plants have a higher chlorophyll content and greater vigor, they also produce more plant material. This results in a higher near-infrared reflectance, which is indicated by the characteristic red color of infrared images. By analyzing the data from the trial plots – and before they'd even set foot in the field – the farmers and crop specialists knew exactly what part of the soybean field required more care and attention.

In the control center: the working environment of a modern farmer is becoming increasingly complex. The potential is immense. Today, an unprecedented amount of data is available as the basis for well-founded decisions. Agriculture, informatics and sensor technology are combining into an interdisciplinary science that could help secure the food supply for a growing world population.

Digital technology for weed-free fields

Efficient management requires concrete data – and that is particularly true in farming. "I was the technical director of an approximately 250,000-hectare agricultural holding in Ukraine for a few years. We were using many digital farming approaches there, but it was difficult to assess how successful they were." explains Dr. Ole Peters. But now the Technical Director of Bayer's Digital Farming team wants to leverage his experiences back then. The digital products that he and his colleagues are developing are focused on determining how crop protection and seed products can be optimally applied to individual zones of the field at the relevant time. "We want concrete, binding instructions that are delivered simply and quickly to the farmer in the field," says Peters. In this way, Bayer's Crop Science Division could be responsible for a field's entire output in the future. "That could mean that we guarantee farmers who follow our recommendations what we call a disease-free field – in other words, a field in which we rule out the possibility of a yield-relevant spread of plant diseases through the application of our technologies rather than no diseases at all," explains the Bayer expert. "Our recommendations enable farmers to use precisely as much crop protection as absolutely necessary and no more." In this way, Bayer is contributing to resource-preserving agriculture. "We're helping farmers all over the world supply the world's growing population with sufficient food," says Peters.

then have the tricky task of working out exactly how these four areas interact with one another. "We have to run several computational models to find this out. It's the only way to provide farmers with accurate, profitable recommendations," explains Peters.

More targeted application means lower pesticide quantities

The researchers also store information in their databases about the efficacy of the crop protection agents – for instance, at which stage of growth certain herbicides are most effective in controlling weeds. When combined with the field data, this information allows crop protection products to be applied to exactly the square meter that needs them – and nowhere else. As a result, less of the active substance is required. In the summer of 2016, the team of experts tested a timing and dosage schedule for the first time on selected farms throughout Europe.

"These new technologies also make it possible for us to generate individualized crop protection agent recommendations," explains Menne. The experts at Bayer use what are termed application maps to do this. "These give the farmer information about the best dosage rates for our products for each individual patch of land." Farmers will also be able to create these maps themselves in the future by scanning the QR code on the packaging of any Bayer crop protection product with their smartphone. Special Bayer software then generates a map – based on the latest satellite images, soil or topograph-

User-friendly: a standard tablet computer (photo below) is all that's needed to take part in the digital agriculture of the future. Rolf Schmidt (photo above), a Bayer employee at the Laacher Hof trial center, checks the condition of the oilseed rape field from the tractor cab.

ical data – and matches the information to the scanned product and the relevant field. Says Menne, "Modern crop sprayers can read these application maps and precision-apply the crop protection agents wherever they are needed."

Precision agriculture increases yields, lowers costs and protects the environment

"By helping farmers to budget better for every grain of seed and milliliter of crop protection agent in the future, we can help avoid potential harvest losses, increase yields globally – and go easy on the environment as well as the farmer's pocket," explains Menne. When collecting data, he and his colleagues also give a great deal of consideration to data protection issues. "It's not our aim to horde agricultural data," says Menne. "But we do need concrete information from farmers to make our analytics work." Nonetheless, it is vital for Menne and his team that the farmers are ensured transparency and control over their personal data." After all, the objective for the Bayer researchers is to assist farmers with new, digital tools that will enable them to get the best out of their soil. ■

Anne-Katrin Mahlein

"Remotely monitoring large areas of crops"

research *spoke to Dr. Anne-Katrin Mahlein from the University of Bonn about how plant diseases can be quickly identified.*

What does big data bring to arable farming?

Diseases and deficiencies often go undetected until the crops exhibit clear symptoms – in other words, when it's actually too late to intervene. This can lead to major yield losses. If farmers are able to make decisions on the basis of information provided by modern sensor technology and intelligent software, they can run their farms more efficiently.

How can your hyperspectral cameras help farmers?

Plants reflect sunlight and hyperspectral cameras capture these reflections in a large number of wavelengths or 'bands'. This allows us to collect very sensitive and detailed information about plants and their physiology. We obtain information about pigment balance in the visible light range, about leaf structure and water balance in the near-infrared range and about constituents and water balance in the shortwave infrared range. Ailing plants have different spectral signatures from healthy ones.

What can this information ultimately be used for?

The aim is to use this technology to monitor large areas of crops so that we can identify plant diseases and stress caused by lack of water or nutrients from afar. By analyzing the light spectrum, it is possible to identify pathogens and even the severity of infections. This will enable farmers to respond quickly and use crop protection measures or fertilizer to prevent yield losses.