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STRATEGIC DISCUSSIONS FOR NEBRASKA 2017

UNIVERSITY OF NEBRASKA–LINCOLN

BIG DATA

MANAGING THE FUTURE'S AGRICULTURE AND NATURAL RESOURCE SYSTEMS


BIG DATA

"Part of that changing environment is using the university's scientific knowledge and creative works to improve lives for people and animals, not just at home, but everywhere."

Michael Boehm

Big Data Overview

HARNESSING INFORMATION, DRIVING SOLUTIONS

By Michael Boehm
University of Nebraska Vice President for Agriculture and Natural Resources
University of Nebraska–Lincoln Harlan Vice Chancellor,
Institute of Agriculture and Natural Resources

Big data is the incredible flow of information that surrounds each of us, every day. "Big Data: Managing the Future's Agriculture and Natural Resource Systems" is the title of this 2017 issue of Strategic Discussions for Nebraska.

The stories in this publication were written by students majoring in Agricultural and Environmental Sciences Communication, based on interviews they conducted with University of Nebraska–Lincoln scientists who use the best-available, data-driven technologies in their research.

Big data tools identify patterns and habits, not only in research, but in manufacturing, logistics – even ordering items online. Computing technology has evolved, too; today's cell phones have more computing power than NASA had when it conducted the Apollo missions.

Computing technology drives today's precision agriculture, using unmanned aerial vehicles, robots and sensors to increase production efficiency and reduce water use. The health of people and animals is improved through new treatments discovered through research and analysis of research data. Cameras capture images every hour in the entire Platte River basin so scientists can learn about changes in the river and the water fowl that rely on it.

Everywhere we look, data is being collected and the tools and minds required to interpret the data are harnessing information that drives solutions. But technical solutions aren't enough. We also have to understand what it means to be human – how we take this information and use it, ethically, to benefit the world. Sensors can tell us the context, but human ethics guides the use of the data for the common good.

At the University of Nebraska–Lincoln, we've hired scientists in disciplines that represent the newest areas of research, all of whom rely on the massive amounts of data generated by the newest technologies. Some of these disciplines are genomics, transcriptomics, metabolomics and proteomics. These "omics" specializations came along with modern molecular biology and research that has allowed us to sequence the entire DNA of a human or animal. We're also hiring faculty members in bioinformatics – the science and the mathematics necessary to understand the stories data have to tell.

We're encouraging collaborations across disciplines to generate new ideas that one scientist might not be able to find alone. A story in this publication features Yufeng Ge, an assistant professor of biological systems engineering, and James Schnable, an assistant professor of agronomy and horticulture. They are collaborating on measuring the physical traits of crop varieties through imaging chambers at the Greenhouse Innovation Center on Nebraska Innovation Campus.

In this publication, you'll find stories about our university's scientists not only conducting research, but teaching students and extending research findings to people who can use it in Nebraska and around the world. After all, that is the spirit of the land-grant mission, established by the Morrill Act of 1862. It is as critical and relevant today as it was then.

THE MORRILL ACT OF 1862

Justin Smith Morrill, Representative from Vermont, 35th Congress

On July 2, 1862, President Abraham Lincoln signed into law a bill that donated land to each state for the establishment of colleges to provide a liberal and practical education to the "Industrial class," or the common person. These colleges would provide instruction in agriculture, military tactics, the mechanic arts and classical studies. Because of the land granted to each state and territory, the Morrill Act of 1862 became known as the land-grant act.

Sponsored by U.S. Congressman Justin Smith Morrill of Vermont, the bill allotted 30,000 acres of public land for each sitting senator and representative in Congress to establish these colleges. Morrill could not have known the future impact this law would have in providing equal opportunity to education to people in the United States and its territories.

Today, there are more than 100 land-grant institutions in the United States and its territories, each focusing on teaching, research and outreach – taking new knowledge to the people.

The University of Nebraska was founded on February 15, 1869, and designated a land-grant institution under the 1862 Morrill Act.

HATCH ACT OF 1887

The Hatch Act of 1887 provides funding for agricultural research programs at state land-grant agricultural experiment stations in the 50 states of the United States, the District of Columbia and in the U.S. territories.

Hatch research activities involve a range of options related to agriculture, land use, natural resources, family, human nutrition, community development, forestry and more and can be local, state, regional or national in scope. A further requirement of the Hatch Act of 1887 is that new information is to be extended to the public.

SMITH-LEVER ACT OF 1914

The Smith-Lever Act of 1914 created a Cooperative Extension Service within each land-grant institution. Cooperative Extension, a partnership between the USDA and agricultural colleges, helps to extend information produced by the research of scientists within each college's experiment station.

THE MORRILL ACT OF 1890

The Morrill Act of 1890 also established funding for land-grant institutions specifically for African-Americans, sometimes called "1890 schools." These 16 public institutions, plus one private institution, are among the more than 100 historically black colleges and universities in the United States. The Morrill Act of 1890 also forbade racial discrimination in admissions policies for institutions receiving these federal funds.

EQUITY IN EDUCATIONAL LAND-GRANT STATUS ACT OF 1994

The Equity in Educational Land-Grant Status Act of 1994 provided land-grant status for certain American Indian colleges and institutions, bringing higher education to reservation communities. The act directed the Secretary of the Treasury to establish a 1994 Institutions Endowment Fund and the Secretary of Agriculture to make capacity-building grants to these institutions.

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES

The University of Nebraska–Lincoln Institute of Agriculture and Natural Resources (IANR) is all about people and the food, energy, water and natural resources that sustain them. IANR innovation in the land-grant mission areas of teaching, research and Extension places Nebraska on the leading edge of food production, environmental stewardship, human nutrition, business development and youth engagement.

The Institute of Agriculture and Natural Resources comprises the College of Agricultural Sciences and Natural Resources (CASNR); the Agricultural Research Division (ARD); Nebraska Extension; and the ARD and Extension components of three departments in the College of Education and Human Sciences.

The Institute of Agriculture and Natural Resources is committed to growing the future of Nebraska's people, businesses and communities.

ABOUT STRATEGIC DISCUSSIONS FOR NEBRASKA

Strategic Discussions for Nebraska is a program in the University of Nebraska Institute of Agriculture and Natural Resources (IANR). The mission of the annual publication is to communicate research-based science so it can be understood by the general public.

A Strategic Discussions for Nebraska publication has been produced annually since 2008, each focusing on a different overall topic.

This year's publication has been produced by a team of university students in the spring semester of 2017 during the capstone course for their major in Agricultural and Environmental Sciences Communication, in the Department of Agricultural Leadership, Education and Communication. The course provides a learning experience similar to those they may encounter in the workplace, emphasizing the accurate, clear and objective communication of science-based information.

During the course, students learn about scientific research being conducted at the university and the diverse funding sources required to support that research. They interview scientists from many disciplines and write stories based on those interviews.

The stories in this publication were reviewed by the sources and approved for publication.

Media specialists from IANR Media provided videography and video editing expertise, which may be accessed online at sdn.unl.edu. University Communication provided photography, graphic design and website expertise. IANR provided funding, business and liaison services for the production of this publication.

As coordinator and editor of this publication, I express sincere appreciation for the original vision and financial support of the Robert and Ardis James Family Foundation, which founded Strategic Discussions for Nebraska in 2007.

Please visit our website, sdn.unl.edu, where you will find this complete publication and a video montage of scientists explaining the research that is changing the world.

Thank you for your interest in our publication!

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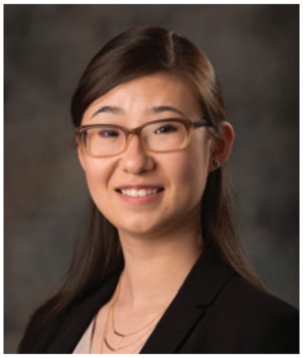

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Interview with IANR Vice Chancellor Michael Boehm
By Lauren Stohlmann

TO BUILD, ENHANCE, PROGRESS

The Morrill Act may have founded the land-grant university system in 1862, but Michael Boehm finds it to be thriving at the University of Nebraska–Lincoln in 2017.

Boehm became University of Nebraska Vice President for Agriculture and Natural Resources and Harlan Vice Chancellor of the university's Institute of Agriculture and Natural Resources on January 1, 2017.

Boehm said the university's main responsibilities reflect the land-grant university values of teaching and learning, research and innovation, outreach and engagement, and his role is to facilitate that work. "I liken myself to be a choreographer or a conductor of an amazing symphony," he said.

THE LAND-GRANT MISSION

"The story we all know about the land-grant system is the miraculous outcome during the height of one of the darkest times in our nation's history – the height of the Civil War," Boehm said. "You get the sense that education wasn't just for the privileged; it was really for the citizens of this fledgling nation."

The land-grant university system was set up to ensure educational access to the citizens of the United States. "But it had a twist," Boehm said. "It came with discovery and engagement agendas to make sure we were focusing our research and scholarship on issues that would enhance the vitality of local communities.

"And so, that's the spirit of the land-grant, and it's as vital, critical and relevant today as it was when Abraham Lincoln signed the Morrill Act into law," he said. "It's a moral obligation that we have because of its direct connection to the people, the place and to agriculture. I've come to a place that 'gets' that."

There are 109 land-grant universities in the United States and its territories; they often are referred to as "the people's universities." The University of Nebraska truly is the people's university, Boehm said; not only does it help our students learn, it also serves the state's residents through one-on-one outreach.

ADDRESSING CHALLENGES

The Institute of Agriculture and Natural Resources' base on the East Campus of the university has a statewide reach. Its main focus areas are people, and the food, water, natural resources, businesses and communities that sustain them.

It's a progressive, global organization. Some of the most recognized scientists in the world are working on challenges such as hunger, poverty, animal and human health, new treatments and vaccines for animal and human diseases and sustainability of natural resources and the environment. Boehm, a scientist himself, understands the need for diverse, collaborative, leading-edge scientists and technology to solve these, and other challenges.

"We have a footprint in so many parts of the world right now; our faculty and staff are global in their scope. These are global grand challenges that we talk about, whether that's poverty, or how we're going to feed a growing world, or how we are going to treat the planet so we have a durable, resilient, sustainable ecosystem," he said.

POPULATION

The world population is expected to increase to more than 9 billion before 2050, which will result in increased demands on water and natural resources to feed that population.

"I absolutely believe Nebraska has a critical role today, but the potential for having an expanded global role is huge," Boehm said. Nebraska's distinctive agroecosystem, he explained, ranges from the Panhandle, where there is a high elevation, low rainfall and sandy soils, to the eastern part of the state, which is nearly at sea level and has more rainfall and glacial till soils. Between west and east are the Sandhills and rich farmland, under which lies the High Plains Aquifer (also called the

Ogallala Aquifer) that provides water for crop irrigation, livestock, manufacturing and people. Nebraska's agroecosystem from west to east is a robust, living laboratory for IANR's researchers, with global applicability.

MORAL OBLIGATIONS

Boehm believes the university has a moral obligation to Nebraska's people, to the state and to agriculture. Nebraska is a place that shares a common vision and purpose of connecting the university to residents in all 93 counties of the state, while driving the institute forward.

The current world population of more than 7 billion includes "the bottom billion," he said – the people in the world who are chronically hungry or literally starving. The Institute of Agriculture and Natural Resources priorities are not only global; they're also local, to the point of looking at poverty, hunger, health care and children in Nebraska's cities, towns and rural areas – and how IANR can engage in issues affecting people.

Even though it doesn't seem possible in a food-producing state like Nebraska, Boehm said 13.2 percent of Nebraska's people are food-insecure, in both urban and rural areas.

"Nearly 250,000 Nebraskans wonder where their next meal is coming from, and of those Nebraskans who are hungry, 100,000 of those are children. That comes back to thinking about the future," he said. Many Nebraskans must drive a long way to buy groceries or access health care, often on a tight budget.

"I think the potential is in our children and in a changing environment," he said. Part of that changing environment is using the university's scientific knowledge and creative works to improve lives for people and animals, not just at home, but everywhere.

Nebraska and the Institute of Agriculture and Natural Resources integrate systems very well, Boehm said.

"It's figuring out where we can harness the intellectual capacity and then really invest in those places that allow us to bring together all the talent that we have to help make a difference in the world."

WHO'S MISSING?

A critical component to maximizing the impact of the university depends on recognizing, talking about and appreciating differences and respecting individuals' dignity, he said.

"We need everyone engaged to achieve the kinds of impacts IANR hopes to make. We absolutely need everybody's best," Boehm said.

Engagement in teaching and research can't occur effectively if the university doesn't look like and embody the diversity of Nebraska.

"We have to pay attention to every single piece of difference and in some manner, look like and embody the communities we're trying to engage," he said. "As a leader, I try to model the behavior that does not blame, but rather creates safe spaces for the different stories, narratives and implicit biases to be exposed, explored and leveraged. The way I'd like to handle it in IANR is simple – for various communities and cultures within IANR, ask the simple question: 'who's missing'? What's missing when those voices and those perspectives are absent?' And then the hard question is: 'what are we going to do about it?'"

ABOUT BOEHM

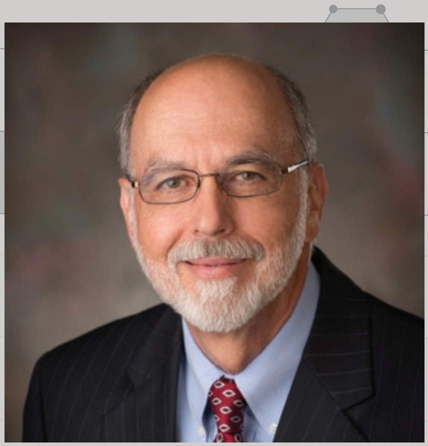
Boehm was a first-generation college student who attended a liberal arts college in Ohio for his undergraduate education. There, he learned about his passion for science and for humanity. He understood that science was important and parallel to that, the understanding of what it means to be a human and how humans engage in the world around them. He earned master's and doctoral degrees from Ohio State University, where he was a professor of plant pathology, becoming a frequently published and recognized authority on turfgrass diseases and on the management of Fusarium head blight of wheat and barley. He served as chair of the Department of Plant Pathology and as vice provost for academic and strategic planning at Ohio State prior to coming to Nebraska.

Boehm's leadership style is an amalgamation of his personal and professional journey, including his nearly 21-year military career. He joined the Army Reserve in 1985 and trained as a combat medic. He was called to active duty after the September 11, 2001, terror attacks, serving as a microbiologist with the U.S. Navy as a testing specialist for bio-threat agents.

As a reservist, Boehm said he lived with one foot in the military world and one foot in the civilian world. "It was practice at keeping two opposing views of the world in focus at the same time, and to understand how things that seem diametrically opposed actually live some way in harmony," he said. At the same time, Boehm developed as a leader.

"One of the most valuable lessons I learned in uniform, first and foremost, is that it is about the mission and it's about your team." Teams who trust their leaders and one another are effective, he said.

"If you don't have trust, whether it's with your family, friends or colleagues, then you might just as well hang it up." Trust is his foundation, he said, and right on top of that are the U.S. Navy's core values of honor, courage and commitment. His other values include transparency, teamwork and inclusivity.



Interview with Ron Yoder
By Shelby Andersen

WHY FOCUS ON BIG DATA?

Scientists have the ability to collect hundreds of data points in a single second with information from just one simple sensor. Multiply that times all kinds of sensors and all kinds of science and it's easier to understand the challenges of what's often called "big data."

Science has evolved into the collection and statistical analysis of data that will help to solve big problems such as global food production and sustainability of natural resources, said Ron Yoder, associate vice chancellor of the Institute of Agriculture and Natural Resources (IANR) at the University of Nebraska–Lincoln.

WHY BIG DATA?

Starting in the late 21st century, Yoder said, the world entered into what has been called the "digital age." Yoder said entry into the digital age greatly expanded the capability to collect large data sets, but the concept of big data is more about complexity than it is about the size of the data set. "It's about the ability to analyze those large data sets, including analytical techniques and methods that extract the desired information. That's what big data is about."

Analysis of data benefits Nebraska and Nebraskans, whether the information comes from sensors, genes, location systems or other sources, he said. "In the Great Plains region, those benefits can mean using the resources more efficiently and effectively to produce agricultural commodities and manage the great natural resources systems we have," Yoder explained. "We're only on the threshold of where we can go with understanding the data we collect and how we collect it."

Soils and water are the fundamental resources for growing crops and animals, Yoder said, citing the Sandhills in central Nebraska as an example of a sensitive ecosystem that must be managed in a way that ensures its future.

"We want to ensure that in producing agricultural commodities in Nebraska, we're doing that with the smallest environmental impact on the resources that we've been blessed with," Yoder said.

"The capability to collect and analyze detailed information allows us to make better decisions and to manage better," he said. "We can be much more effective in using the resources we have and can minimize the impact on the overall system in which we're producing food." For instance, in row crop agriculture, technology and data analysis have shown that crops can thrive using less water, pesticides and added nutrients, minimizing the inputs needed to produce crops.

An example of an application of research, Yoder said, is a study that showed by simply placing each seed of corn perpendicular to the row at planting, yield can be increased by 14 percent.

NEW FACULTY, NEW SCIENCE

Yoder said today's smartphones are thousands, if not millions of times more powerful than a computer of the 1970s. The ability to accomplish tasks computationally is where all the scientific disciplines are going, whether in the social sciences or hard sciences, he added. And that's where it's necessary to have people with specific skills, to analyze the data, find new ways to look at data and to find answers to questions no one had previously considered.

Because of this, the Institute of Agriculture and Natural Resources began a hiring initiative in 2012 in which new faculty members were hired over five years in key areas, many of which rely on data collection and analysis.

"Having computational sciences as a central portion of who we are and what we do is key to maximizing our effectiveness," Yoder said. "We are making wise investments in research and education."

Scientists are working toward increasing efficiency in agricultural and natural resource systems, leading to the hiring of faculty members in six key areas:

- Computational sciences
- Science literacy
- Stress biology
- Healthy humans
- Healthy agricultural production and natural resource systems
- Drivers of economic vitality for Nebraska

"We attempted to hire individuals who would fit into that idea of solving problems using a transdisciplinary approach," Yoder said, which means building teams of researchers from multiple disciplines. These transdisciplinary partnerships will improve researchers' abilities to ask questions and get better answers, extracting the most useful information from large data sets.

Scientists' discoveries will require them to make these transdisciplinary partnerships. "If you do that around the world, you bring in different environments that people work in – different climates, different soils, different water resources – and you bring in the cultural aspect that maybe someone working in one location doesn't think about," Yoder said, particularly in the areas of health, environmental policy, and agriculture and natural resources.

The hiring of new faculty members was funded by retirements of longtime faculty members, increased enrollment and updating budget priorities, Yoder said.

THE LAND-GRANT MISSION

Land-grant universities were established by the Morrill Act of 1862, which set aside federal land for colleges that would educate people about agriculture and the mechanic arts. As Nebraska's land-grant university, the university has since grown to include a wide range of degree programs.

Yoder oversees the daily operations of IANR, including nearly 40,000 acres of land across Nebraska; more than 1,600 faculty and staff members; IANR academics; and Nebraska Extension. The thousands of acres of university land are used for research, teaching and Extension, and provide access to the varied climate and topography across the state.

Yoder said the land-grant mission means serving Nebraskans. However, the research, teaching and Extension work has relevance to people all around the world. Nebraska's soil types and climate compare to numerous other countries. These similarities allow for the exchange of information and development of new areas of the world for agricultural production.

Interview with Archie Clutter
By Victoria Talcott

THE RIGHT PEOPLE AT THE RIGHT TIME

Hiring scientists to solve global challenges.

The Agricultural Research Division is the research engine of the University of Nebraska–Lincoln Institute of Agriculture and Natural Resources. Its dean, Archie Clutter, oversees more than 300 faculty members with research appointments in 15 academic units and two university colleges.

"Our programs cover everything from fields and landscapes to healthy children, healthy communities and healthy economies," Clutter said. There is a statewide ARD infrastructure, including research and Extension centers in North Platte, Scottsbluff and Concord, augmented by satellite facilities around these centers. There are thousands of acres of farm and ranchland on which the university faculty and staff conduct research and carry out Extension programming.

Nebraska's diversity of natural growing environments produces many kinds of plants and animals, and university scientists study the soils, plants, animals, water and climate in every part of the state. People with knowledge of technology and of each discipline fuel that research engine.

Increasingly, solutions lie in the collection, analysis and storage of data resulting from research into the genomics of crop and animal production; the DNA and RNA sequencing that underpins plant and animal sciences; human and animal health; precision farming and irrigation; and more. "We are creating a formal, strategic approach to building capacity around big data and creating tools and solutions for big data," Clutter said. The applications address global challenges.

GRAND CHALLENGES

There are more than 7 billion people on Earth today, but there will be at least 2 billion more before 2050, Clutter said, and those people will need to eat. Increasingly, people will have the financial resources to allow them to demand and purchase a greater diversity of food and a higher quality of food, he added.

"We have the grand challenge of feeding more than 9 billion people in just a few short years with the same amount of resources," Clutter said, noting that Nebraska is positioned well to help lead solutions based on Nebraska scientists' work.

In 2012, just after Clutter came to Nebraska to be dean of the Agricultural Research Division, then-IANR Vice Chancellor Ronnie Green (now university chancellor) started a conversation on campus around feeding the world in an efficient and environmentally responsible way.

"We essentially said to our faculty – 'within the framework of our mission, which is food, fuel, water, people and landscapes – what is it that you can achieve, what are the problems you can solve, what are the questions you can answer?'" Clutter said. Based on that question, the work began to identify goals, teams and gaps in those teams. One gap, they learned, was expertise in computational sciences and big data issues.

The faculty also identified priorities, outcomes and impacts and funding for hiring scientists in disciplines that would help Nebraska become a leader in addressing global challenges. Those disciplines were – and still are – computational sciences, stress biology in plants and animals, systems of agriculture and natural resources, and science literacy.

21ST-CENTURY FACULTY

The initial hiring phase attracted tremendous pools of candidates, Clutter said, and 38 faculty members were hired over nearly every one of the Agricultural Research Division's 15 units.

"We planned to hire faculty who would be successful here and stay for their careers," Clutter said. By the end of 2016, a total of 140 faculty members had been hired, which meant about 40 percent of the IANR faculty members were new to the university. Of those 140, about 110 have research appointments.

The IANR leadership has formed a Faculty Success Network within the Institute of Agriculture and Natural Resources to provide support and opportunities to new faculty, Clutter said. The group meets monthly with Clutter and IANR Associate Vice Chancellor Ron Yoder, and faculty have informal opportunities to share ideas across disciplines. "We want to ensure their success," Clutter said.

That transdisciplinary sharing of ideas models the collaboration now typical among scientists.

"In our division, we can build teams that take systems approaches by combining those different disciplines and partnering with others outside our disciplines," Clutter said.

Collaborations include entities such as the Food Innovation Center on Nebraska Innovation Campus, the University of Nebraska Daugherty Water for Food Global Institute and the University of Nebraska Medical Center. "It's the Nebraska Food for Health Center that is connecting basic plant science to food science, such as the study of the gut microbiome; the Food Allergy Research and Resource Program; the Department of Food Science and Technology, including The Food Processing Center. It all connects with human health," Clutter said. "There even is clinical space at the Food Innovation Center where we can connect all the pieces for this Nebraska Food for Health right there at Nebraska Innovation Campus." The Nebraska Food for Health Center is an initiative to combine strengths in agriculture and medicine, with the goal of improving lives of people around the world. It is led by Andy Benson, professor of food science and technology.

GENERATING, ANALYZING DATA

The genomics of crop and animal production generates massive amounts of sequence data, as do studies of proteins and their various applications such as understanding food allergens. Precision irrigation and other aspects of precision farming also generate tremendous amounts of data, he said, as does the state-of-the-art high-throughput plant imaging technology in the Greenhouse Innovation Center on Nebraska Innovation Campus. That is where university scientists from complementary disciplines translate gene discovery into more resilient crops.

"The application is to tie the plants' genomic information into important traits like tolerance to drought and disease," Clutter said. The imaging technology captures plant images at every stage of plant growth, which represent massive amounts of data, he added.

"These are examples of how we are building programs to address important problems," he said. "We are looking for ways that we can leverage the strengths of the university and the state."

Interview with Jennifer Clarke
By Lauren Stohlmann

DATA

Changing the face of science, academics.

Today's science is complex, collaborative and intensely focused on solving important global problems, such as growing enough food. Part of today's scientific complexity involves the collection and analysis of immense amounts of data.

Jennifer Clarke is a professor of food science and technology at the University of Nebraska–Lincoln; she also is director of the university's Quantitative Life Sciences Initiative. The initiative began in 2011 as a university-wide program focused on data science research and training.

"One of the biggest challenges right now is increasing food production and being good stewards of our natural resources. That involves life sciences, which are critical to our future. These are questions that I don't think we can solve without collecting data. Right now, that means a lot of data that is more complex and higher-volume than anyone anticipated. It requires expertise in several different areas, as well as the ability to communicate the challenges," Clarke said.

Clarke defines the commonly used term "big data" as having "so much data that you can't store it all; you can't keep it all at one time. It's more data than we can handle as human beings." Computer systems are essential for managing and storing the data involved, she said. Big data goes beyond spreadsheets and tables to "one step beyond your comfort zone," Clarke added.

Clarke also works with faculty in the Nebraska Food for Health Center, which brings together strengths in agriculture and medicine from throughout the university system. The missions of the center focus on developing hybrid crops and foods to improve human health, and preparing a workforce to lead in research and innovation in the food and health industry. The research generated includes multiple millions of data points, all of which must be processed, analyzed and stored.

QUANTITATIVE LIFE SCIENCES INITIATIVE

The Quantitative Life Sciences Initiative is a faculty collaboration of scientists who learn from one another, both about other scientific disciplines and about data science. As director, Clarke works with faculty and stakeholders to provide quantitative training so they can understand data and analyze it with the goal of obtaining information people can use. The initiative is an interdisciplinary effort that involves multiple research areas: bioinformatics, business analytics, computational sciences, digital humanities and digital arts, earth science and natural resources, mathematics, precision agriculture and statistics.

Clarke said scientists, including herself, had been collecting increasingly large amounts of data in the years preceding the founding of the Quantitative Life Sciences Initiative. "The university decided it would benefit a lot of people if we had someone whose area of specialty was data in the life sciences and who could work with faculty and stakeholders and help recruit more faculty who have experience in that area," she said.

SHE WAS HIRED.

"I see my role as providing direction for data in life sciences; it covers everything from biochemistry and genetics all the way to plant imaging," Clarke said, choosing the areas in the life sciences where she believes the university can have a big impact. Clarke has three main goals for her position: ensure that the university's educational programs are up to date and that students are learning the skills they will need in their future careers; interact with stakeholders and private partners to be sure they are engaged in data science; and provide faculty with the data expertise they need to conduct their research.

She also recommends emerging areas of research, faculty recruitment and training of students in these areas for the university to consider.

Clark said she sees top universities around the world are starting programs similar to the Quantitative Life Sciences Initiative – interdisciplinary programs in which students and faculty learn from one another, across disciplines.

The Quantitative Life Sciences Initiative is funded through federal grants and nonprofits, matched by the University of Nebraska system, Clarke said. Among federal funding agencies are the National Science Foundation, the National Institutes of Health and the United States Department of Agriculture.

DATA'S PURPOSES

Clarke said determining gene function is difficult; without data collection and analysis, it couldn't be done. High-capacity computers can sort the data quickly and provide answers to specific questions.

Once statisticians have obtained data, the principal researcher determines the questions to be answered and the data scientist puts the data into a computer, using a distinct formula. The computer analyzes the data and, based on the formula and the researcher's question, the computer generates an answer.

Clarke gave the example of a plant biologist interested in making a crop produce a higher yield. Some scientists want to make a plant more drought-tolerant. The researcher might look at the data of a whole plant genome and try to determine the role of each gene. Through computer-generated analysis of the data, the scientist will learn more about the plant and eventually, predict how it might react in specific circumstances, like drought.

According to Clarke, interpreting this data only leads to more research. Once the computer generates the answer to a question, the researcher might ask another question to refine results or extend the research.

COMPLEX BIOSYSTEMS DOCTORAL PROGRAM

Based on rapidly advancing science, Clarke and her colleagues saw the need for a new, collaborative doctoral program in Complex Biosystems that would train students across departments and disciplines, so work began in 2013 toward such a program. "For example, in the life sciences, we want students to also get information about how to work with data and provide some basic training in the quantitative sciences," Clarke said.

The Complex Biosystems Ph.D. program is directed toward graduate students who expect to apply statistical and computational approaches to multiple areas of biology, including human health, medical biochemistry, microbial metagenomics, ecology, evolution and plant systems.

Each student is encouraged to have two program mentors; one from life sciences and one from quantitative sciences, as well as one advisor. Students come to weekly meetings and to a weekly seminar, as well as to a development series.

"These are students who want to combine data with life sciences," Clarke said. "For instance, if they're doing work in plant systems, then they might be collecting a lot of data on the soil composition. They're collecting data as they are understanding a life science system," she explained. "They come to campus because they want that combination of skills."

For more information on the Complex Biosystems doctoral program, visit: www.unl.edu/gradstudies/prospective/programs/ComplexBiosystems

For more information about the Quantitative Life Sciences Initiative, visit: bigdata.unl.edu

ANIMALS

"We are responsible for genetic improvements of our agricultural species," Morota said. "We do this by doing two things: first, we identify genes that are involved in economically important traits and second, we perform genomic evaluations of individual organisms."

Gota Morota

Interview with Clinton Krehbiel
By Aliesha Dethlefs

THE BIG PICTURE

Team effort critical to sustainable animal production.

Today's production of a billion kilograms of beef – more than 2 billion pounds – requires 35 percent less land, 20 percent less feed, 12 percent less water and 30 percent fewer animals than it did in 1977.

These production efficiencies were realized through science and research collaborations, according to Clinton Krehbiel, who became head of the Department of Animal Science at the University of Nebraska–Lincoln in 2017.

AND THE TIMING COULDN'T BE BETTER.

In the late 1800s, it took 100 years for the world to grow to 1 billion people, Krehbiel said; the last gain of 1 billion people has taken only 12-14 years. By 2050, there will be 9 billion global mouths to feed, with the same or fewer natural resources. Sustainable production of more animal protein will be a part of the solution to feeding that increased population.

"We're thinking about where we need to go from here to make ourselves even more efficient for the future," he said.

SCIENCE TIMELINE

"The Morrill Act of 1862 provided federal land to states to establish universities so they could train students in agriculture and the mechanic arts," Krehbiel said, noting that the University of Nebraska still understands the value of the land-grant mission.

"We are here first to serve the next generation; the students we train. That is the main purpose of the land-grant mission," Krehbiel said.

In 1887, the enactment of the Hatch Act added a research component to the Morrill Act and the 1914 Smith-Lever Act added Extension, so the work of University of Nebraska scientists encompasses teaching, research and extension of research to the people who need it.

Significant events have occurred every 10-15 years since 1940 that improve animal health and increase animal production, Krehbiel said, much of it thanks to the land-grant mission:

- 1940s: artificial insemination began to have an impact on the production of dairy and beef cattle.

- 1950s: growth technologies impacted animal growth and efficiency.
- 1950s: compounds to fight parasites were initiated.
- 1970s: feed additives to increase efficiency and weight gain benefited the cattle industry, especially in the feedlot industry.
- 1990s: new antimicrobial medications came on the market, curing bacterial infections in cattle and contributing to animals' well-being.
- 2000s: beta-agonists came into use as feed ingredients to help animals make the most efficient gains.

"Now, we're looking at history and considering what the next 100 years need to look like," Krehbiel said.

QUEST FOR EFFICIENCIES

The term "big data" comes from the adoption of technologies, especially since the early 2000s, that allow scientists to generate and capture a great deal of information, Krehbiel said.

"For example, the genome of the bovine has been sequenced, and there are 3 billion base pairs of DNA. If you're looking at unique genotypes of several different breeds of animals, you can see how rapidly the amount of data multiplies," he said. An example of generating large amounts of research data is the GrowSafe System® used in university research facilities. The system uses an ear tag on each animal with a unique number; the system reads the number and measures the feeding behavior and the feed intake of each animal housed in the same pen of a feedlot.

"All that information adds up to a whole lot of data points in a hurry," he explained.

The ultimate goal of animal science research will be to improve production systems and enhance efficiencies to be sustainable for the future, Krehbiel said. Part of sustainability will be to select the genotypes of animals for environments where there are limited water resources, in which the animals gain the same level of performance or production, with less water. Plant researchers are doing similar research, he said, developing plants that can produce a yield even in heat, drought or flood situations.

SYSTEMS RESEARCH ACROSS DISCIPLINES

The University of Nebraska is moving toward integrated approaches to solving problems by thinking about the entire system of food production.

"How does soil health impact nutrient capture of that soil to impact plant growth? How does that soil health ultimately affect what that ruminant animal might consume? How does that interaction affect the nutrient profile of the steak you might eat?" Krehbiel asked. Then, the animal delivers nutrients back to the soil that the plants and soil microorganisms are going to re-integrate into that entire ecosystem. There is a lot of information to be modeled to determine that impact of those relationships, he added.

This "systems approach" is a collaborative effort to bring together many minds to solve a single problem," he said. Ultimately, someone must take all of the research information – all of those data points – and analyze, summarize and model it, Krehbiel said. In the soil-plant-animal sciences, that means determining the "downstream effects" of even the smallest changes.

CHANGING SPECIALTIES, EDUCATION

The ability to capture billions of research data points also generated the need for bigger computers, more data storage space and faculty who understand the value of big data. More academic departments are hiring faculty who understand bioinformatics – the combination of biology and mathematics – to analyze and model the information, Krehbiel said, with the goal of understanding those "downstream effects" of changes throughout the entire growth system.

The advent of big data, bioinformatics and a need to supply food for a growing population also influences the teaching of both undergraduate and graduate students, Krehbiel said. There are more courses being developed around the systems approach and also around the science of big data, especially at the graduate level.

More than 350 undergraduate students and 75 graduate students study in the university's Department of Animal Science. Internationally recognized faculty offer courses in breeding and genetics; ruminant and non-ruminant nutrition; reproductive physiology; and meats. The department has evolved to include dairy and beef cattle, sheep, swine, poultry, horses and companion animals.

Interview with Daniel Ciobanu
By Shelby Andersen

MOLECULAR GENETICS

Swine health has surprising similarities to human health.

Daniel Ciobanu's research is not just used for curing swine diseases and improving animal well-being. It also translates into human health and well-being since pigs are similar to humans.

Even though genomics in human medicine was recently introduced for disease prevention, treatment choice and outcome, sophisticated molecular genetics technologies have been used for many years in the swine industry and in agriculture in general, according to Ciobanu, who is an associate professor of molecular genetics in the University of Nebraska–Lincoln, Department of Animal Science. He uses genomic approaches in his work, which means he can look at the whole genome instead of a single gene.

"We can genotype a DNA sample coming from a pig for 60,000 to 800,000 DNA polymorphisms. If we identify a genomic region associated with disease susceptibility for a particular pathogen, we can focus on certain genes within that region and find the source of the differences in susceptibility," he said.

"If we are able to come up with a mechanism that controls replication of a certain virus in swine, that knowledge can be used to better understand the pathology of similar viruses in humans – how the virus infects, how the virus replicates, and what kind of strategies can be used to treat these viral diseases in humans," Ciobanu said. For example, when a cancer diagnosis is made, doctors can use the DNA profile to determine the best treatment.

Ciobanu's findings will help medicine move towards prevention of diseases.

PORCINE CIRCOVIRUS TYPE 2 (PCV2)

Ciobanu studies the Porcine Circovirus 2 (PCV2), which causes a pig's immune system to malfunction and makes the animals susceptible to other diseases. One of the other common viral pathogens in swine is the often-deadly Porcine Reproductive and Respiratory Syndrome Virus (PRRSV).

"PCV2 comes first and tricks the immune system so it doesn't recognize danger anymore, then a different pathogen, such as PRRSV, comes along. The immune system doesn't recognize it and cannot fight against the second pathogen and the symptoms are quite severe," Ciobanu explained.

Household disinfectants, like bleach, are effective in killing some pathogens, but not the PCV2 virus. Instead, professional-grade disinfectants must be used. Even so, it is difficult to eliminate the virus and a daunting challenge to disinfect an entire farm.

Over the course of his research since his arrival at the university in 2009, Ciobanu and his collaborators have been able to pinpoint two regions of the pig genome that are associated with susceptibility to PCV2 associated disease.

"We are pretty confident that we have identified a gene and mutation responsible for differences between pigs regarding viral replication. If one pig has a favorable genotype, the PCV2 doesn't replicate very well compared with the unfavorable genotype," he said.

DATA IN SWINE GENETICS RESEARCH

The swine genome is made up of 2.7 billion nucleotides, according to Ciobanu. There are 1,000 pigs in his Nebraska research project. Every step in collection and analysis of genetic information is important and must be done to perfection, he said. Every week, each pig must be weighed and samples of blood collected. The samples are analyzed for viral DNA and antibodies specific to the PCV2 pathogen, which determines whether the pathogen is in the animal's system. The next step is to genotype each pig for 60,000 DNA polymorphisms.

Ciobanu has involved both graduate and undergraduate students in the collection of samples for the research and calls the undergraduate students "the backbone of my research." The current graduate student conducting the fine genetic dissection of PCV2 susceptibility is Lianna Walker. She was introduced to the PCV2 research during her Undergraduate Creative Activities and Research Experience (UCARE) in her senior year at the university.

Approximately 100,000 total data points have been collected from tissue and blood samples over the course of this research. Ciobanu explained that these data points are then analyzed statistically with help from one of Ciobanu's collaborators, Stephen Kachman, a professor of statistics.

According to Ciobanu, the results of this research will be beneficial to all sectors of the swine industry. Commercial swine breeding companies specialize in providing swine genetic material, such as semen, to commercial swine operations, which gives swine producers the option of selecting genetic material for desired traits, Ciobanu said. He hopes that someday, one of those selection options will include the gene variant responsible for PCV2 resistance so the virus can eventually be controlled.

A world without the PCV2 virus will mean not only better health for animals, but also financial benefits to swine producers, Ciobanu said. Although a PCV2 vaccine is available, it is expensive when an entire herd must receive the vaccine. Selection for the resistant variant of the gene will be permanent.

Ciobanu relies on colleagues from his own and other disciplines to assist with research collection and analysis, including Kachman; Hiep Vu, an assistant professor in animal virology at Nebraska and an expert in PRRSV; Dan Nonneman, a molecular biologist with the U.S. Meat Animal Research Center, a USDA Agricultural Research Service facility in Clay Center, Nebraska; and Graham Plastow, a professor in animal genomics from the University of Alberta in Edmonton, Canada, who also is working with PRRSV.

"I think collaboration is extremely important to help you move forward and to cover for the expertise that you don't have," Ciobanu said.

IMPORTANCE

Ultimately, Ciobanu hopes the science produced through his work and the work of his collaborators will be adopted by swine breeding companies nationwide. Swine breeding companies have the most valuable animals and can select for favorable genotypes, he explained; swine producers multiply the valuable pigs; and commercial farms cross different genetic lines.

"We are going to provide a gene and a DNA polymorphism that impact viral replication. They can use this in selection and everybody will benefit," he said. "The impact will be more money in farmers' pockets, because if they have pigs that have more natural resistance, they can either provide less vaccine or just not vaccinate. The additional benefit is that the animals will have better natural resistance, less mortality and less suffering."

Interview with Ron Lewis
By Mary Garbacz

SHARING GLOBAL SCIENCE

Solving global problems through technology.

The co-revolutions of supercomputing and molecular genetics are helping to find answers to the world's greatest challenges, like feeding a growing world population with more efficient and disease-resistant plants and animals.

Ron Lewis is a University of Nebraska–Lincoln animal scientist who specializes in quantitative genetics and genomics – the scientific, statistical and computational tools that integrate the enormous amounts of data collected on ranches and farms, and in the lab, to assist livestock producers in their genetic decision-making. Lewis also possesses the international experience that helps him recognize the importance of collaboration, a country's norms and how it all fits into global trade.

Lewis spent two years as a geneticist for the Western Australian Department of Agriculture and 10 years as an animal breeding specialist for the Scottish Agricultural College in Edinburgh, Scotland. Those experiences formed his perspectives on food, fiber, social norms and global trade.

In Australia, sheep and wheat are primary industries and drive the economy and the country's norms, Lewis said. Production systems are designed to make those industries profitable.

In Europe, he said, there are questions about how food should be produced. "It moves the focus from the underlying science to the choices people make based on their perceptions and social priorities," Lewis said. "The discourse in Europe is about personal choices, while in Australia, like Nebraska, agriculture is a key driver of the economy."

FOOD: A CRISIS?

The world population is growing, with an expected crest of more than 9 billion before 2050. Much of that growth is happening in areas where the definition of a food crisis is not whether a consumer can buy a preferred product, but whether there simply is enough food.

Lewis heard a British economist say that for some people, a food crisis is going to the supermarket and not finding the exact loaf of bread they like – perhaps multigrain, with poppy seeds, and sliced thick. "That's a complete change of thinking about food, when we go from 'do we have food to eat?' to making very particular choices. That affects the way people think," Lewis said.

Today, consumers can choose from foods produced in different ways, with certain labels and specific boundaries on production systems. These consumer preferences are important, particularly in communities in which people can buy based on perceptions of their needs and what they find to be acceptable, as opposed to purchasing solely based on need for food. Those preferences have changed in many westernized areas in the last half-century or so, Lewis said.

Those perspectives also come into play in global trade. "You really have to take into account what people perceive to be right or wrong," he said, and provide the options they prefer. Sometimes that means producing food for a specific market, using specific production techniques.

"If we, as a global trader, want to deal with all these different marketplaces, we can't forget about that diversity," he added.

GENOMICS: FEEDING THE WORLD

Genomics is a collaborative area of research into an organism's genes. This research can aid in producing more food for a growing population by helping scientists understand interactions between those genes and the environment in which the organism lives. An animal's genetic makeup can indicate whether it can thrive in spite of extreme weather challenges or poor-quality food. Such an animal would be valued in parts of the world where heat and drought challenge food production.

Researchers now have genomics tools that have accelerated the research process, such as the ability to sequence DNA. That 20th-century research discovery now is used to make better breeding decisions, Lewis said.

"At the end of the 20th century, we had the molecular revolution," he said, which meant understanding where genes are located along chromosomes and how they function and interact with one another. "Now, we can start thinking about the cumulative effects of genes which might affect an animal's growth. For instance, we're producing more milk, and more eggs. We can now ask 'how do genes function to produce these products, which are an accumulation of all their behavior?'" Lewis said.

But that's 2017 research. Selection for desirable traits has been traced back to the 7th century.

A BRIEF HISTORY OF SELECTION

Domestication of animals occurred in about the 7th century, Lewis said; animals were selected based on whether they were docile enough to handle and whether they met a human need, whether it was for transport, food or fuel.

By the 18th century, English agriculturalist Robert Bakewell introduced breeding selection to the country's cattle, sheep and horses. "He was the starting point of thinking about progeny testing and keeping things written down in herd books and registries," Lewis said.

In the 19th century, science moved further toward artificial selection. Gregor Mendel, an Austrian botanist, discovered basic principles of heredity through garden experiments with peas, forming the foundation of modern genetics. In 1859, Charles Darwin, an English scientist, published Origin of Species, which described his theory of evolution by natural selection.

"They moved us toward thinking about the scientific underpinning of genetics; Darwin, with ideas of natural selection with fitter genotypes being more successful in producing progeny for the future, and Mendel, thinking about what was called 'particulate inheritance,'" he explained. Particulate inheritance was the idea that elements (now known as genes), produce a flower of a certain kind or a leaf of a certain length. "We started with understanding some of the biological underpinnings of genetic change," he said.

By the 20th century, ideas evolved quickly. "We started to understand what a chromosome was, and what DNA was, and how that links back to some of the ideas of Darwin and Mendel," he said. The collected centuries of science led researchers to make better breeding decisions for animal well-being and efficiency.

One of the key developers of animal genetics was Gordon Dickerson, Lewis said. Dickerson was an animal scientist in Nebraska's animal breeding program from 1967-1987. "When people think of these pioneer animal geneticists, he is among that group," Lewis said. University Chancellor Ronnie Green, also an animal geneticist, was Dickerson's last doctoral student.

By the end of the 20th century, the molecular revolution arrived on the scene and scientists began to understand where genes are located along chromosomes, how they function and how they interact with one another. "We're really digging down to understand how genes express themselves, individually and in combination, to impact our agricultural products," he said.

There has been a tremendous computational revolution along with the molecular revolution, as huge amounts of data must be managed using supercomputers. "If we don't have the tools to handle the data related to the way animals perform, we're not going to get very far," he said. These advancements have produced new disciplines of scientists, including bioinformatics specialists who make sense of the enormous amount of information generated by studying the genome.

WHY STUDY GENES?

"We're interested in how animals grow; we're worried about their well-being and about their impact on the environment and the sustainability of our production systems. At the end of the day, sustainable production systems need to take a lot of things into account," Lewis said. Integrating genomics tools will allow scientists to do a better job of addressing challenges that historically have been too complex to solve. These advancements also affect producers' finances, people's perceptions of science – and health of humans.

"We're going to be able to develop tools that are tailored to individuals in human medicine," Lewis said. "The next part of the revolution is moving toward understanding the functionality of genes and how that functionality impacts biological pathways."

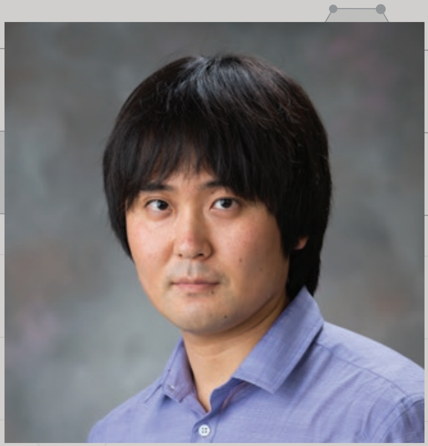
A UNIVERSITY'S ROLE

Lewis said it is important for a university to enter the international dialogue about science and the opportunities it offers. "But also, it's recognizing and being willing to get into the debate about some of the challenges that we need to address and be conscious of issues that cause concern," he said. "In the longer term, I think that's going to define what we do in our agricultural industry."

DEFINITIONS

Genetics: Genetics helps scientists to understand what genes do. It is about understanding variation in performance, or expression, due to the genes inherited, and to predict how characteristics of parents – sires and dams – will be transmitted to their progeny. "If we do a better job with that, we're able to do a better job in choosing parents to produce progeny with more favorable attributes," Lewis said.

Genomics: Genomics allows scientists to determine the DNA sequences of sets of genes on specific chromosomes or even the entire genome of a given organism. From that "genomics allows us to look deeply at the functionality of those genes – what they do to affect performance – individually and in combination," Lewis said.



Interview with Gota Morota
By Mary Garbacz

MORE EFFICIENT PLANTS AND ANIMALS

History, goals of quantitative genetics.

Agricultural producers have been selecting desirable traits in animals and plants for centuries with the hope of breeding better, more efficient species. Eventually, producers collaborated with universities' scientists and extension educators to take advantage of genetic research.

Today, scientific discoveries in the field of genetics are fast-tracking the selection of animal and plant traits by using gene selection to make them more desirable, efficient and resistant to stress.

The quantitative genetics discipline started in the early 1900s, with research by Sir Ronald Fisher and Sewall Wright. Fisher was an English statistician and biologist who combined genetics and statistics with Gregor Mendel's 1800s research into biological inheritance theories. Wright was an influential American geneticist. Quantitative genetics today involves so much data that supercomputers and scientists with specialized training are needed to process the data and answer research questions.

The University of Nebraska–Lincoln has long been known for excellence in quantitative genetics, which attracted Gota Morota to a faculty position at Nebraska in 2014. Morota is an assistant professor of animal science and quantitative geneticist. He combines biology and statistics to connect a wide range of phenotypic data with high-dimensional "omic" information, such as genomics and gene expression, in animals and plants. Genetic research has been conducted for decades. The sequencing of DNA has become easier and faster because of advances in technology, allowing analysis of an enormous amount of data, Morota said. "For example, in animal breeding, we analyze more than 1 million animals in genetic evaluations, so the discussion about 'big data' is not new to us," he added.

When the data sets become too large to store on physical computers, Morota said they will be stored on "the cloud" – vast servers that store data and make software and services available through the internet.

VALUE OF RESEARCH, ANALYSIS

The challenge in analyzing large amounts of data is how to extract meaningful and useful information, he said. Morota's task is to separate the genetic signal from nongenetic factors such as "noise," and investigate how the genetic signal information influences phenotypes of interest. He and other scientists assess how well genomic information can predict yet-to-be observed phenotypes and test the data to verify that specific genes are important to a particular process.

"We are responsible for genetic improvements of our agricultural species," Morota said. "We do this by doing two things: first, we identify genes that are involved in economically important traits and second, we perform genomic evaluations of individual organisms." The goal is to select individual plants and animals with high genetic potential to make the next generation, he explained. Morota's work involves collaborating with other scientists to understand the biology and the collection of data, followed by Morota's analysis of the data to help answer the research questions.

Morota was drawn to biology, statistics and computer programming as an undergraduate student in Japan. He built on those interests in his master's and doctorate coursework at the University of Wisconsin-Madison. "I took a lot of courses in statistics during graduate school," he said. Morota said quantitative genetics uses statistical approaches to determine the genetic merits of individual organisms.

In his work at Nebraska, he develops and tests statistical methodologies in both animal and plant genetics. "I think there are many things an animal geneticist can learn from a plant geneticist and vice versa," Morota said. One of his university scientific collaborators in plant science is Harkamal Walia, an associate professor of agronomy and horticulture who specializes in plant physiology.

"Dr. Walia is interested in finding genes that are responsible for resistance to abiotic stress traits," Morota said. Abiotic stress includes unavoidable stresses such as climate change and extreme heat or drought. "Our goal is to find a genetic basis of abiotic stress – which genes and pathways are involved." Selection of desirable traits allows plants to grow – even thrive – in areas of the world where growing food is challenged by extreme conditions.

Interview with Matt Spangler
By Morgan Zumpfe

FROM BIG DATA TO BETTER BEEF

Using genomics to improve beef cattle.

Beef geneticists like Matt Spangler collect and analyze data from millions of cattle, each with 20 or more different traits, including hundreds of thousands of animals that have been genotyped with 50,000 to 250,000 DNA markers.

It is that magnitude of data that requires sophisticated computing systems and specialists trained in genetics, statistics and bioinformatics to make sense of it all.

SPANGLER IS ONE OF THOSE SPECIALISTS.

An associate professor of animal science and Extension beef genetics specialist at the University of Nebraska–Lincoln, he works with a team of other scientists and graduate students to analyze data and find solutions to aid in the profitability and sustainability of beef cattle production while also focusing on the desires of beef consumers.

Improvements in feed efficiency and reproductive success are traits that ultimately affect the cost of meat in the marketplace, Spangler said, while improvements in tenderness and composition affect the consumer's eating experience.

"Things of that nature we know are under genetic control," he said. "We can use this data to develop tools we can use to select animals that are superior in those traits."

DNA: A QUANTUM LEAP

An international collaboration of scientists sequenced the bovine genome in the first decade of the 21st century, publishing the sequence in 2009. That breakthrough science has allowed Spangler and other scientists to identify DNA markers related to differences in animals for production efficiencies and consumer preferences. That knowledge will streamline the process of selecting animals that grow larger and more efficiently and are more likely to conceive regularly, Spangler said.

"We're trying to take a large mass of data and distill it down so producers can use it to make animals more profitable, to make an end product that consumers want," he said.

The university's Department of Animal Science has six faculty members dedicated to breeding and genetics, including molecular biologists, quantitative geneticists like Spangler, and theoretical quantitative geneticists who develop the statistical theory to solve genetics problems, he said. Spangler's collaborations with faculty members in the Department of Statistics who have a keen interest in genetics and solving industry problems also are critical and highly valued.

This collaborative model extends to the U.S. Meat Animal Research Center (USMARC) in Clay Center, which is a United States Department of Agriculture Agricultural Research Service facility.

"Think of that center as a world-renowned think tank of animal scientists that all day long, focus on issues related to animal agriculture and solving those issues," Spangler said. "We work very closely with this huge team of scientists."

Industry also engages in problem-solving research, from individual producers to breeding companies and breed associations. Currently, Spangler said the university's Department of Animal Science has collaborations with several U.S. beef breed associations and with both commercial and seedstock swine companies. The collaboration of scientists uses data to answer questions and provide solutions to the people and businesses who can benefit from the information.

EFFICIENCIES = PROFITS

"We want to ensure that producers have the tools to select for not only increased revenue, but decreased cost," Spangler said. These efficiencies include how much food an animal actually eats – and how that amount can be reduced and still maintain animal growth and ultimately, producer profitability.

Improvements in selection tools so they are more accurate – earlier – help producers to make more informed selection decisions.

"That's where genomics comes in. We can gather genomic data, or genotypes, on individual animals at birth – actually, before birth," Spangler said. "We can already have a prediction on that animal's genetic merit as a parent long before they have the opportunity to reproduce." Having that knowledge early in an animal's life increases the accuracy and speed with which genetic change can be made, he added.

Spangler said as an Extension specialist, he meets with producers and industry representatives to explain the university's research and encourage producers to adopt new techniques. An annual meeting of seedstock producers and breed association representatives showcases the university's Weight Trait Project. This project represents a collaboration of scientists at the university, USMARC and the beef industry. This allows key technology adopters to participate in cutting-edge research and to be among the first to "test drive" emerging technology. One of Spangler's University of Nebraska–Lincoln colleagues is Steve Kachman, a professor of statistics, who speaks to the group every year.

"They love listening to him," Spangler said. "You'd think a brilliant statistician like him and the people with 'boots on the ground' would speak different languages, but they love listening to him. I think we've bridged gaps through that project."

GENETICS: A LONG TRADITION

Genetic selection is not new. The tools have become more sophisticated since the mid-1800s, when Gregor Mendel discovered basic laws of inheritance, and when Charles Darwin developed his scientific theory of evolution by natural selection.

"These scientists started the thinking about how characteristics are passed from one generation to another," Spangler said.

It was the mapping of the bovine genome – which, all of a sudden, provided the genomic information that became the foundation of commercialized DNA tests and of the term "genomic selection." Genomic selection involves selecting animals based on the cumulative effects of hundreds of thousands of DNA markers, now possible around the world and across species, he said.

In recent years, Spangler said scientists are sequencing an individual animal's entire genome and obtaining millions of DNA markers. Those data, those millions of markers, must be analyzed.

"The data always holds the truth. And we have to know how to ask the right questions," Spangler said, to obtain information that is useful.

The science has evolved so far that now, Spangler said, it is possible to actually edit a part of a genome, which would dramatically change the rate of genetic change, particularly in terms of reducing susceptibility to disease. Allowing the use of this technology should be based on the merit of the science, he added.

LEADING THE WORLD

So how does this benefit not only the people of Nebraska, the people of the United States, but also the global population?

"We are using science and developing new science, always with the end user in mind," Spangler said. "I think that, across disciplines, we need to be leaders and come up with solutions that really improve the lives of all the people that we serve. I want people to understand that as scientists, we don't simply think about the next federal grant. And we don't think about the next journal publication. We truly think about how this is going to help people."

Interview with Vishal Singh and Andrew Uden
By Jayde Olson

FITNESS TRACKERS MEASURE CATTLE HEALTH

Quantified Ag's technology improving cattle well-being.

Wearable fitness devices can monitor a person's sleep, heart rate, steps taken in a day and other activity. Similar technology now can be incorporated into cattle feedlots, with the goals of treating sick cattle promptly, improving animal welfare and helping producers be more profitable.

Quantified Ag started in the summer of 2014 by Vishal Singh and moved to the University of Nebraska–Lincoln's Nebraska Innovation Campus in the summer of 2015. Singh said the company creates biometric ear tags that continuously read animals' behavior, mobility and temperature through sensors on the tag, triggering an LED light, making it fast and easy to identify sick animals.

The information from the tags is transmitted wirelessly to a central base station in the feedlot and the data stored on cloud servers. Cattle producers can log in anywhere, on any device and see which animals are being flagged by the system as showing early signs of illness.

Singh is co-founder and Chief Executive Officer of Quantified Ag; Brian Schupbach is co-founder and Chief Technology Officer; Andrew Uden is co-founder and Chief Operations Officer.

ABOUT THE TECHNOLOGY

While fitness trackers only transmit data from a single human to a single phone a few feet away, the Quantified Ag technology transmits information up to two miles and shows data from a huge number of animals – but also makes it easy to find a single animal in all that data.

"What we're able to do is identify sick animals, usually several days before pen riders can," Singh said, which can result in animals being treated earlier and separated from other animals before the illness can spread. Pen riders are horse-mounted feedlot workers whose main job is to identify and remove sick and injured cattle from the feedlot.

Uden said Quantified Ag performs data analysis reporting and deep-level machine learning that tells people more about the animals than has ever been possible, based on the data in the ear tag and the analysis of the data comparing animals' biometric patterns. It is possible to see disease forming sooner than would be possible simply with the human eye, he added.

"Long term, that will help with more precision use of antibiotics and more precise management of animals – which ultimately helps our customers save on their overall costs and develop more trust in their product," Uden said.

Ultimately, big data drives all the decisions – data points from thousands of cattle, multiplied by scores of criteria – and also generated from Quantified Ag's animal health platform of apps related to inventory management and veterinary management. Quantified Ag is a fully cloud-based, almost autonomous system accessible by cell phone.

Humans are only 40 to 60 percent accurate at finding a sick animal in a feedlot, but Quantified Ag technology may push that into the 90 percent category, Uden said, and animals can quickly get the attention they need.

"We're trying to take a lot of the human error and human elements out of the system, at least for identifying those animals. Once the animal is flagged, that's when a human being, such as a veterinarian, becomes involved to make that physical diagnosis," Uden said. "I think we're on the cutting edge of moving people into precision livestock management."

Quantified Ag's investors are beef people – cattle producers, veterinarians, nutritionists – who, Uden said, look at the Quantified Ag technology and say "finally, something that's not just another antibiotic, but actually a device that can help us find just the animals we need."

According to the Quantified Ag team, treatment information, as well as lot and performance data, can be stored securely on the company's cloud-based servers for consumers to see. The animals' health data is encrypted with the same technology used by banks and hospitals. The online portal allows users to access and process meaningful reports of all their newly collected data.

"Our job is to make sure the information collected from the data is easily digestible. When the data comes in, it has to be presented so a cattle producer can see the data from a huge number of animals, but then quickly drill it down to find one specific animal if they want," Singh said. "It has to be simple to start with, and then they can dig into different layers of data analysis and record analysis," he added.

"Long term, the data allows for more transparency to consumers. I think it sends a message to consumers that we're doing our best to take care of these animals," Uden said.

REVOLUTIONIZING THE CATTLE INDUSTRY

The Quantified Ag technology is important, Singh said, because it affects the food chain and beef consumers by giving them confidence in an industry that makes sure their beef came from healthy cattle. Singh expects the technology to reach not just producers in the United States, but also in other countries that either produce beef or consume beef from the United States.

"Quantified Ag has the opportunity to change the beef industry for the better, because cattle producers will be able to lower their losses, improve efficiencies and overall, produce a better beef supply. It's systems like this that will come into play in agriculture that will build a more sustainable future of food," Singh said.

Uden said the cloud-based software is easy to demonstrate to producers using just a mobile phone, and it is starting to change mindsets among producers and feedlot managers.

The Quantified Ag technology can bridge gaps in the beef industry and lead to more informed decisions in the beef industry, Uden added.

"Nebraska is a great place. We've typically been one of the more technologically advanced states in agriculture, so there are a lot of producers right here at home who want to be testing and trying our biometric ear tag sensors," Uden said.

"The data always holds the truth. And we have to know how to ask the right questions."

Matt Spangler

NATURAL RESOURCES

"When you get different disciplines looking at overlapping questions from different perspectives, you can get really creative ideas on how to solve global problems."

John Carroll

Interview with John Carroll
By Emily Long

FROM EARTH TO SKY AND EVERYTHING IN BETWEEN

The School of Natural Resources serves the public through research, teaching and outreach.

The School of Natural Resources at the University of Nebraska–Lincoln embraces the land-grant mission of teaching, research and extension. And according to its director, John Carroll, the school's objective is to "assist society in managing the land and its resources in the best way we can."

Carroll's goal is for the school to be an international leader in natural resources education, research and outreach in its three core areas of Applied Ecology, Applied Climate and Spatial Science, and Environmental Science.

Natural resources include everything from soils to water, ecosystems to biodiversity, and climate, too. Each of the resources is especially important in Nebraska, where so much of its land and economy is rooted in agriculture. This also means natural resources science is complex and includes challenges, such as feeding a growing population without damaging the environment, dealing with changes in climate, and solving society's problems while protecting valued areas, animals and resources. Finding balance is key.

The impact of research conducted in the School of Natural Resources (SNR) includes the state, but also the region, nation and the world.

"We cut across so many different fields and disciplines and across important questions that are facing the world," Carroll said. "We look at issues related to limited resources. We conduct research on water, soils and climate change — issues that affect everybody across the globe." Much of the research is collaborative, which is made easier because the 80 SNR faculty members work in the same building on the university's East Campus, he said; seeing one another regularly makes it more natural and convenient to work on projects together, and the outcomes have a larger impact.

"When you get different disciplines looking at overlapping questions from different perspectives, you can get really creative ideas on how to solve global problems," Carroll said. "Solutions scale up from very localized to global in each of our areas of research focus."

RESEARCH AND DATA

Carroll said natural resources scientists are quantitative by nature and have been accumulating research data by collecting soil and rock samples and recording measurements of water levels, water quality and climate variables across the state for more than 100 years. This includes scientists' long history of research and data collection of the Ogallala Aquifer, which is part of the High Plains Aquifer System. The Ogallala Aquifer underlies most of Nebraska, providing water for the state's crops, animals and people.

"I think our scientists' monitoring of that system over decades has helped inform decision-makers – everyone from energy companies to farmers to city planners – so they can make better decisions about how we manage the aquifer," Carroll said.

He added that with current technologies, SNR's scientists are able to obtain "huge amounts" of geological data through remote-sensing methods that also can help monitor the complex aquifer. Remote-sensing data is collected not only from airplanes, but also from federally-operated satellites, unmanned aerial vehicles or drones, and sensors placed on and just above the ground.

The enormous amount of data generated through monitoring natural resources, from the Earth to the sky, must be stored in an accessible way, analyzed and explained, Carroll said. Increasingly able and effective computer and data generation systems make storage the easy part; the challenge is in interpreting the information so informed decisions and accurate predictions can be made. Yet, SNR scientists are able to project short-term and long-term temperatures and precipitation trends for individual towns and cities using scientifically sound models and historic data inputs.

"These types of skilled data analyses are crucial and important if we are going to do a better job of managing our natural resources for the future," he said. "Being in an agricultural state, SNR has a lot to provide in the attempt to balance food, water and resource needs for an expected world population of 9 billion people in the not-too-distant future. We use our science and big data to answer those questions more effectively."

SNR CENTERS AND UNITS

Housed in the School of Natural Resources are nine research centers and units that conduct collaborative research with universities throughout the world, providing opportunities for students and faculty to look at questions and problems from different perspectives:

ARCHAEOLOGICAL, BIOLOGICAL AND FORENSIC LABORATORY

The Archaeological, Biological and Forensic Laboratory offers a range of contract services for apiculturists, archaeologists, biologists, forensic scientists and geologists.

CENTER FOR ADVANCED LAND MANAGEMENT INFORMATION TECHNOLOGIES

The Center for Advanced Land Management Information Technologies (CALMIT), a center of excellence for education and research, focuses on remote sensing, geographic information systems and global positioning systems.

CONSERVATION AND SURVEY DIVISION

The Conservation and Survey Division, the natural resource survey component of the School of Natural Resources, is a research, service and data-collection unit. Its mission is to investigate and record information about Nebraska's geological history, its rock and mineral resources, the quantity and quality of its water resources, land cover and geography, as well as the nature, distribution and use of its soils.

GREAT PLAINS COOPERATIVE ECOSYSTEM STUDIES UNIT

The Great Plains Cooperative Ecosystem Studies Unit (CESU) is a network of 12 federal agencies and 20 academic institutions and a nongovernmental organization. The Great Plains-CESU encompasses a broad geographical portion of the Great Plains and includes a group of scientists in grasslands, ecosystems studies, and natural and cultural resources management.

HIGH PLAINS REGIONAL CLIMATE CENTER

The High Plains Regional Climate Center scientists work closely with scientists from other regional and federal climate centers to develop and implement services and programs that provide timely climate data and information to the public.

LONG-TERM AGRO-ECOSYSTEM RESEARCH NETWORK

The Platte River-High Plains Aquifer is one of 18 established Long-Term Agro-Ecosystem Research (LTAR) networks across the United States. Current research emphases are on addressing present-day and emerging issues related to profitability and sustainability of agro-ecosystems.

NATIONAL DROUGHT MITIGATION CENTER

The National Drought Mitigation Center (NDMC) helps people and institutions develop and implement measures to reduce societal vulnerability to drought through preparedness and risk management. The center has a global reputation for assisting local governments, regional tribes and national governments all over the world in managing drought and risk management planning related to agriculture and society in general and relies on global data collections to be able to offer that assistance.

NEBRASKA COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT

The mission of the Cooperative Fish and Wildlife Research Unit Program is to train graduate students for careers in natural resource research and management, conduct research that will create new information useful for management of natural resources and provide technical assistance to its cooperators in the federal government, universities, states and nonprofit organizations.

NEBRASKA STATE CLIMATE OFFICE

The Nebraska State Climate Office (NSCO) is dedicated to delivering science-based climate services at the local and state level. Its scientists monitor weather and climate, provide climate services and engage stakeholders in climate conversations. The Nebraska Mesonet, a statewide weather observation network with nearly 70 locations across Nebraska, is part of the Nebraska State Climate Office.

THE UNIVERSITY OF NEBRASKA–LINCOLN SCHOOL OF NATURAL RESOURCES

A snapshot

LOCATION: Hardin Hall, University of Nebraska–Lincoln East Campus

DIRECTOR (SINCE 2013): John Carroll, Ph.D.

2017: 300 undergraduate students, 150 graduate students, 80 faculty

HISTORY

- A University of Nebraska natural resources unit was discussed as early as 1965
- Many units merged to form the School of Natural Resources (SNR) in 1980
- School of Natural Resources Sciences (SNRS) was formed in 1997, representing both the College of Arts and Sciences and the College of Agricultural Sciences and Natural Resources, which is part of the Institute of Agriculture and Natural Resources
- The School of Natural Resources (SNR) was established in 2003

THREE MISSION AREAS

- Applied ecology, including the study of plants, animals, prairies, fisheries, forests and ecosystems;
- Environmental sciences, including the study of soils and water; and
- Applied climate science, including climate issues, risk management and natural disasters related to climate. It also includes remote sensing for detection of information for agriculture and ecosystems.

CENTERS AND UNITS

- Archaeological, Biological and Forensic Laboratory (ABFL)
- Center for Advanced Land Management Information Technologies (CALMIT)
- Conservation and Survey Division (CSD)
- Great Plains Cooperative Ecosystem Studies Unit (GP-CESU)
- High Plains Regional Climate Center (HPRCC)
- Long-term Agro-ecosystem Research (LTAR) Network
- National Drought Mitigation Center (NDMC)
- Nebraska Cooperative Fish and Wildlife Research Unit
- Nebraska State Climate Office (NSCO)

Interview with Michael Forsberg and Michael Farrell
By Bryce Doeschot

'THEY'RE NOT JUST PICTURES'

Platte basin timelapse captures images of a watershed in motion.

A camera placed in the heart of a canyon overlooks a bald eagle's nest near Fort Collins, Colorado. Five hundred miles away, a separate camera faces the Platte River. In between the two cameras are more than 50 additional cameras, all part of the Platte Basin Timelapse project. Each daylight hour of each and every day, the cameras capture a photo with the goal of allowing others to see the Platte River Basin watershed in motion.

A watershed is an area of land that separates water flowing to different rivers, basins or seas. The Platte River Basin stretches across parts of Colorado, Wyoming and Nebraska, supports agriculture and grassland ecosystems, and harbors more than half of the Ogallala Aquifer.

"The idea behind this project was to show how water moves through a system from the highest point in a watershed to the lowest point in the watershed," said Michael Farrell, a 43-year veteran of public broadcasting and an award-winning documentary producer.

"We have cameras that are looking at natural features. We have cameras that are looking at agricultural landscapes in both ranching landscapes and crop field production," said Michael Forsberg, a conservation photographer and Senior Fellow with the International League of Conservation Photographers, who also has ties to National Geographic.

Together, Farrell and Forsberg created the Platte Basin Timelapse project in 2011. Farrell and Forsberg serve as assistant professors of practice in the Department of Agricultural Leadership, Education and Communication and as courtesy assistant professors of practice in the School of Natural Resources in the College of Agricultural Sciences and Natural Resources (CASNR) at the University of Nebraska–Lincoln. The Platte Basin Timelapse project is in partnership with the University of Nebraska Center for Great Plains Studies.

IN THE BEGINNING

Farrell and Forsberg began working together while Farrell produced a documentary based on Forsberg's book: "Great Plains: America's Lingering Wild."

"We spent months traveling around the Great Plains going to various locations," Farrell said.

Forsberg noticed that the places they visited along the Platte Basin had changed since he visited the locations first to take pictures for his book and then to record the documentary with Farrell.

"The land had changed, the people had changed, the situation had changed," Forsberg said. "You can write about it, you can measure it, but what if you could see it?" Forsberg brought up the idea, which would lead to something much bigger than either expected.

"At one point we're driving along, and Mike (Forsberg) said 'You know, it would be really interesting if we could timelapse the entire Platte River Basin,'" Farrell said.

Both Farrell and Forsberg had developed a love for the Platte Basin through their work, and each had the desire to extend the project. The two men wanted to create a story about the Platte Basin and water.

"I was trying to get people to think about where their water comes from, what is a watershed anyway, and why does it matter," Forsberg said.

PARTNERING IN THE PLATTE BASIN

With an idea in mind, Forsberg and Farrell knew they would need key partners to assist in the funding of the project.

Forsberg said the two began to look for funding for the project. The result was a partnership between the university and Nebraska Educational Television, which continued until 2017, when they and the project moved to a partnership with the university's Center for Great Plains Studies. Funding has expanded to include other entities, including:

- University of Nebraska–Lincoln Institute of Agriculture and Natural Resources
- The Cooper Foundation
- The Platte River Recovery Implementation Program
- The Nebraska Corn Board
- The Nebraska Soybean Board
- Daugherty Water for Food Institute
- Claire M. Hubbard Foundation
- Other private donations and grants

After securing funding for the Platte Basin Timelapse project, Farrell and Forsberg set out to place cameras across the Platte Basin.

Forsberg said he and Farrell decided on the locations to address the three key sources of water in the Platte Basin: weather and climate, clouds in the sky and snowpack in the Rocky Mountains.

The cameras are placed across the Platte Basin with camera systems as high as 20 feet, to cameras placed at ground level. Each camera is placed in a weatherproof housing box, which contains additional technology that allows images to be taken; images are sent to a cloud-based system and stored on computers in Lincoln, Nebraska.

The first cameras were placed throughout the 90,000-square-mile basin and began capturing images in 2011.

CAMERAS AS RESEARCH, DATA

To date, the Platte Basin Timelapse project has captured more than one million photos but according to Farrell, capturing the image is only the beginning of the story.

"The first order of business is all these images are available on our website (plattebasintimelapse.com)," Farrell said.

Creating timelapse images includes combining a sequence of images to record the changes that take place over time.

In addition to sharing videos and photos on the website and social media, the Platte Basin Timelapse project works with organizations to create educational materials.

"We're finishing up a grant for the Nebraska Environmental Trust that has let us create modules that teachers can use in the classroom based on our imagery, and based on other imagery that we're providing in addition to the timelapses," Farrell said.

The partnerships also extend into production agriculture. The Platte Basin Timelapse project has worked with both the Nebraska Soybean Board and Nebraska Corn Board to create materials that can assist the two boards.

"We put timelapse cameras on center pivots, so we actually have cameras that are moving around in a big circle now, and getting wet during the summer watching corn grow, watching soybeans grow, so we're using the raw materials to create visualizations that will allow us to tell stories, or to educate people, Farrell said.

Forsberg believes that in addition to the creative and visual aspect, the images can be used in cooperation with scientists who are conducting field work.

"Besides stories with these images another great value to them is that they're just not pictures. You can see erosion, deposition and sedimentation, and you can see how removing a cedar tree off a landscape helps the prairie come back," Forsberg said. "These cameras are also research tools."

Forsberg said scientists and researchers currently are adding sensors on the landscape to measure a variety of data, such as water quality. By working with the Platte Basin Timelapse project, the researchers have access to see the landscape in addition to the data from the sensor.

Additionally, in the future, the Platte Basin Timelapse project will be featured in a documentary film for public television.

EXTENDING THE EXPERIENCE

When leaders at the university agreed to fund the Platte Basin Timelapse project, one contingency was that Farrell and Forsberg would both teach a course about how to tell a story about something that changes over time.

"We created a class called Digital Photography and Storytelling, with the idea that we would have a cohort of students every year that would get to learn a lot of the tools that we're applying in the Platte Basin Timelapse project," Forsberg said. Each semester, university students are able to enroll in the course with Forsberg and Farrell. The classroom often includes trips into the fields where cameras are set up as part of the project.

Forsberg and Farrell agree that the work they do in the classroom is just as important as the work in the field.

"I can't think of anything better than the teaching part of what I do. If I had to give up all the rest of it, I'd still want to hang onto that," Farrell said.

"There's nothing better than to see that light go on, and see kids struggle, but don't let them slip through the cracks, and help them overcome the challenges, and then come out the other side with something that they can share and show whether or not it's a documentary short film, or it's a multimedia piece, or a website, or something, but it's really rewarding, and I think a tremendous skill set that students need to have today," Forsberg said.

Interview with Troy Gilmore
By Morgan Zumpfe

MONITORING WATER QUANTITY AND QUALITY

Collaborators, data focus on sustainability.

WATER. IT IS EXISTENCE ITSELF.

The science of water quality and quantity is essential, and the University of Nebraska–Lincoln is a leader in that science.

Water from aquifers supplies water for irrigation, livestock, drinking, sanitation, recreation and wildlife, especially in the midsection of the United States.

The High Plains Aquifer underlies sections of eight states in the Great Plains, from North Dakota to Texas. Nebraska benefits from the deepest and widest part of the eight-state aquifer formation. The Ogallala Aquifer, as it is sometimes called, is a formation within the High Plains Aquifer.

Troy Gilmore is an assistant professor and groundwater hydrologist in the university's School of Natural Resources Conservation and Survey Division, where he studies groundwater quantity and quality and extends information to water resources managers in Nebraska and beyond. It's complex science and involves creating materials that are geared toward the needs of specific areas of the state, he said.

Gilmore also focuses on the history and the future of aquifer management. There are areas of the High Plains Aquifer that have been depleted and where groundwater levels have dropped significantly – mostly in the southernmost states, Gilmore said. There are other areas, such as the Nebraska Sandhills, where there is a large amount of water in the aquifer, water that sustains the state's crops and cattle. Some estimates suggest that one-fourth of all agricultural production comes from the High Plains Aquifer region, Gilmore said.

"Nebraska has been blessed with 69 percent of the total volume of the High Plains Aquifer beneath the state, but there are still parts of Nebraska that are facing real challenges with maintaining water levels," Gilmore said. Estimates suggest that up to 80 percent of people who live above the High Plains Aquifer depend on it for drinking water, he said, so much of his work focuses on water quality and the sustainability of the water resources.

COLLABORATIONS FOR SUSTAINABILITY

Sustainability means preserving both quantity and quality of water for future generations, Gilmore said.

Gilmore collaborates with other hydrologists, as well as with engineers, social scientists and educators. He also works with the university's Institute of Agriculture and Natural Resources (IANR) Science Literacy Initiative to make his research easy for the public to understand and use. The Science Literacy Initiative exists to foster a scientifically literate society in which people can make effective decisions related to food, fuel, water, landscape and people. He also works with the university's School of Natural Resources' Human Dimensions researchers, who study humans' interactions with the environment, resolve conflicts, create policies, act as educators and help to improve stewardship.

Gilmore said Nebraska's Natural Resource Districts (NRD) across the state are ideal collaborators. The NRDs are unique to Nebraska and are responsible for managing groundwater in their districts. They have real local influence, he added. Each district has a permanent manager and staff, but a locally elected board of directors.

"That's a model that is being looked at by other states and even other countries as a management model to consider," Gilmore said. "These management districts have done a really good job of maintaining the groundwater in those areas."

Every year, the Conservation and Survey Division assembles an annual report about water levels in Nebraska, and the NRDs are the organizations collecting much of the data that go into each report. The Conservation and Survey Division also partners with the Nebraska Department of Environmental Quality; these collaborations are essential to collect and maintain the databases, which are accessible to the public, Gilmore said.

DATA'S ROLES

Nebraska leads the nation in the number of irrigated acres, which helps propel agriculture to its position as the state's top industry. The need for sustainability of agricultural production, along with water quality and quantity, have led scientists to develop conservation technologies, including sensors. Sensors gauge a crop's need for water, so agricultural producers can apply only the amount of irrigation water a crop needs, saving water and preserving water quality.

Gilmore uses a pressure transducer to monitor water levels in wells. The pressure transducer senses differences in pressure, which assists him in determining water levels. In some cases, real-time groundwater levels are transmitted via satellite, he said.

With more and more sensors being automated and a massive amount of data fed automatically to databases, the need for sensor maintenance and data management increases, he explained. His division manages the electronic issues and equipment failures associated with the sensors, while the United States Geological Survey has been managing sensors and the data generated by real-time streamflow records being fed to the database by way of satellites.

Now, with agricultural water management, center pivot irrigation systems can report pumping rates and irrigation timing in real time. There also is a large amount of weather data that is useful to agricultural producers for informing timely and precise irrigation, Gilmore said.

"There's a huge volume of data that is being gathered and it's going to continue to multiply," he said.

"One of the things that's nice about these huge data sets is that people are mining them and trying to see global patterns or continental scale – or even state-level patterns, understanding the hydrologic cycle or people's influence on it," he said.

"I am excited about studying the management of Nebraska's water resources and translating the science so people who are managing the water can have good information to work from to make the best decisions they can," Gilmore said.

Interview with Martha Shulski
By Diana Marcum

NEBRASKA STATE CLIMATE OFFICE

Monitoring climate, measuring impact on people.

The Nebraska State Climate Office works with outside sources such as the High Plains Regional Climate Center and other university affiliates to collect, analyze, interpret and deliver climate and weather information to anyone who wants or needs it.

"There are various needs and uses for weather and climate information, and so we help people understand how to use the climate information and why it's important to them," according to Martha Shulski, director of the Nebraska State Climate Office. Climatology, Shulski said, is the collection of weather patterns over time, including long-term trends and global climate change. Climatology includes meteorology and the study of weather, but also includes how weather extremes, like drought, affect people and agriculture.

Shulski works with the end users of climate information, tailoring the science to their needs and making it useful for them. For instance, one of her research projects involves both agricultural and climate information, packaged so an agricultural producer or crop consultant can use it in decision-making.

Founded in 2016, the Nebraska State Climate Office conducts research projects, using data from 66 observation stations in Nebraska that constantly monitor and record air and soil fluctuations for immediate and historical use.

"There's a saying that's, 'you can't manage what you don't measure,' and so if we don't measure it [weather and climate], then it's difficult to know what to do and how to deal with it if we don't know what's going on," Shulski said.

CLIMATE RESEARCH, CLIMATE CHANGE

Research conducted at the Nebraska State Climate Office can vary from tracking air and soil moisture levels and temperatures to monitoring possible drought conditions and collecting general weather and climate data information.

It also includes climate change, which Shulski said means different things to different people.

"Climate and climate change impacts everybody and everything," Shulski said.

How these changes affect people can vary depending on where they live and what is important to them.

"If you're in agricultural production, we know the number of frost-free days is lengthening over time, so that is an impact. We know summer temperatures are changing; nighttime lows are warmer and that has implications," Shulski said. In terms of water resources for Nebraska, for example, snowpack in the Rocky Mountains has decreased in the last 50-60 years and is melting earlier, she said, which impacts water managers. New pests and invasive species are migrating north as temperatures warm. Climate changes that Nebraskans don't experience directly include changes in sea level, changing glaciers and snow conditions. But Nebraskans do experience changes in temperature extremes and heavy precipitation events, she said.

Shulski said that changes in drought also can be a result of climate change, citing the 2012 drought that caused crops to fail and water restrictions in Nebraska. She added that climate change could cause droughts to intensify and occur more frequently. If similar droughts were to occur several years in a row, that is an impact that could directly affect families in Nebraska and in market fields such as agriculture and technology, across the nation and internationally. With the help of the Nebraska State Climate Office, possibilities such as extreme droughts and other weather and climate affects can be monitored.

Climate change does not affect every place on Earth at the same rate, so it is important to measure the climate system on a seasonal basis to understand how it is going to impact people.

"It is important that we keep track of what's going on and understand what has happened, then try and make some projections of what will happen in the future," she said. Measurements of temperatures, moisture, wind and other climate conditions are historical information that guide predictions.

Information collection and analysis is continuously improving in both frequency and accuracy. Information is available online in a real-time projection at nsco.unl.edu/climate-data, as well as in predictions of developing weather conditions. A summary of the collected data can be reviewed and placed in historical context. Once in alignment with historical context, data can be examined for potential climate correlation or anomalies.

Measuring weather patterns on a seasonal basis through the state's observation stations results in a collection of statistical and observational data, Shulski said. After it is analyzed by the Nebraska State Climate Office, it can aid in discovering the possible climate impacts on people, both in Nebraska and elsewhere.

IMPACTS IN NEBRASKA AND BEYOND

The research and data can be used to monitor climate and drought conditions throughout the state. This information can then be presented to state agencies overseeing natural resources and water management, or agricultural production. Information from the local and regional level, such as weather observations, also is important at the national and international level.

A responsibility of the Nebraska State Climate Office is engaging with people both in and outside the state and examining how their climate information is being used.

Shulski is bringing agricultural and climate information to producers and crop consultants to help with their decision-making for the upcoming growing season. This helps to inform growers about possible impacts of climate change regarding on-farm management, irrigation and planting times.

"Understanding what's going on in Nebraska certainly has a relevance to what's going on elsewhere," Shulski added. "For example, we're not the only the only state that grows corn in the country or in the world; knowing what's going on locally feeds into the international community."

Interview with Martha Shulski
By Emily Long

NEBRASKA MESONET MONITORS THE STATE'S WEATHER

Can your county sponsor a weather station?

The Nebraska Mesonet is a network of 66 weather-observation stations around the state that continuously monitor air temperature, humidity, precipitation, wind speed and direction, barometric pressure, soil temperature and moisture. The stations provide real-time, research-quality data to scientists and consumers who need or want the information.

However, only 45 counties of Nebraska's 93 have a weather station, and more are needed.

"Our goal is to have one station per county in Nebraska. The more data you have, the better," Shulski said. "A lot of people want to have local data, so if we could get a grid pattern across Nebraska, we can represent the state fairly well."

The total cost of components for one weather station is $15,000, plus a commitment of a $2,600 annual maintenance and operational fee, Shulski said. By sponsoring a weather station, weather conditions can be monitored and the information used for predictions and protecting resources. Data from the weather stations have been used in agriculture; for example, cattle producers use it to see what measures need to be taken to protect cattle. Nebraska Extension and the Nebraska Department of Natural Resources also use the information generated by the Nebraska Mesonet weather stations, Shulski said.

GETTING A WEATHER STATION

County entities often collaborate to fund a weather observation station, Shulski said, including both public and private companies that would find the information to be valuable.

The data are collected via phone modem, connected with Nebraska Mesonet through cellphone and the internet. Each station is powered by solar panel.

The data are available hourly, she said. As the data are coming in, a Nebraska Mesonet staff person is checking to make sure it seems reasonable.

The typical setup of a weather station is a tripod configuration with a solar panel at the bottom. The solar panel is facing south so it can capture the sun from the southern hemisphere. The weather station must be on flat, open ground, away from structures or trees. The locations are determined partly by the sponsors' desires and partly by the best location to get the most accurate data.

Shulski said a Nebraska Mesonet technician sets up each weather station and maintains the station after its installation.

Components of the weather observation stations:

- Tripod setup configuration
- Solar panel
- Gill sun shield
- Temperature and humidity sensor
- Solar radiation arm
- Wind vane/anemometer
- Propeller-type temperature sensor
- Wind vane
- Barometer
- Data logger with battery and communications equipment
- Underground cables
- Precipitation gauge
- Soil temperature and moisture sensors
- Wind temperature sensor

UPDATES

The Nebraska State Climate Office continues to update the weather stations to better serve the agricultural community. In the 2017 growing season, new products were implemented, including a growing-degree-day tracker, Shulski said. The office also is working on having a local, in-house database so that people can have the whole data set at their fingertips.

"The other aspect that they're looking into is notifying people when certain weather events occur. For example, if the wind goes over a certain speed amount or the temperature hits freezing, it will send users who sign up with this service an alert. They'll be notified if their area had freezing temperatures the night before so they know they need to take the right precautions. Whatever identifies as their threshold of interest – it'll send them an alert for that," Shulski said.

For more information and how to sponsor a weather station, contact the Nebraska State Climate Office at (402) 472-6711 or visit mesonet.unl.edu.

Interview with Andrew Suyker
By Breanna Jakubowski

MICROMETEOROLOGY

Measuring climate close to the ground, quantifying photosynthesis, climate change and feeding the world.

The science of climate, and of climate change, is complex and can be difficult to understand. But climate is measurable, making it possible to reveal scientific-based, replicable evidence that shows how it affects plant growth and water consumption. Scientists aren't stopping there, though. Based on research, they are helping farmers adopt new crop practices that, hopefully, will continue to help feed the world.

Andy Suyker is one such scientist. He is a micrometeorologist and associate professor in the School of Natural Resources at the University of Nebraska–Lincoln. A micrometeorologist, he said, studies the physical processes that are occurring from ground level to a few hundred feet above it, including ecosystems such as forests, grasslands and deserts. Suyker also studies turbulence and the exchange of mass and energy between plant, soil, water, lake and ocean surfaces.

"The science we can contribute is feeding all those new souls that we are going to have on the planet, and being able to feed them adequately," Suyker said. "I'm hoping that some of the insights we've been able to develop could potentially help solve one of the biggest issues facing mankind – all those mouths to feed in light of potential global change."

Global change, including climate change and climate variability, affects the ability to produce food. There are two aspects of climate change, Suyker said; first, there is the gradual trend in mean quantities, including temperature and total amount of precipitation.

"The other aspect of climate change is the amount of variability – the day-to-day weather phenomena. For example, more intense thunderstorms, more intense periods of rainfall, more intense periods of wind," he said. There also have been more periods of dryness and drought, he added. All of those factors can have a much bigger impact on productivity of a crop compared with small changes in mean average temperature or total precipitation, he said.

"A few bad weeks, a bad storm, and you lose the yield for the whole year," he said.

Suyker and other scientists have been able to capture, in detail, the evapotranspiration and carbon uptake and how they are affected by the more intense weather phenomena. Evapotranspiration is the amount of water that leaves the plant's surface as water vapor.

"From hour to hour, we can measure how much water came off the surface, how much carbon was taken up by the ecosystem. We get more insight into how the crop canopy is responding to these phenomena. We could potentially come up with mitigation strategies to help offset the negative impact of this greater climate variability that we see," he explained.

WHAT IS MICROMETEOROLOGY?

Micrometeorologists produce a series of measurements that quantify the exchange of carbon between the surface and the atmosphere. Plants photosynthesize and take up carbon; Suyker measures the exchange of carbon and the factors that affect that exchange. The factors include biophysical factors, biomass, leaf area and environmental factors such as winds, temperature and humidity. He also measures the amount of water that leaves the plant's surface as water vapor – evapotranspiration – and the amount of water that leaves the surface from evaporation.

During the growing season, Suyker can measure the net uptake of carbon by the vegetation; in the nongrowing season, he monitors the release of carbon by the ecosystem.

"Soil microorganisms feed on the biomass in the soil and on the surface; the byproduct is carbon dioxide. The carbon dioxide is carried away by the turbulence. With our sensors, we can capture the exchange – the loss of carbon – in the nongrowing season," he said. Over a whole year, he measures the net exchange of carbon and water vapor from the agricultural or natural ecosystem.

DATA-HEAVY WORK

Suyker said the university has been a part of the AmeriFlux Network since 2000. AmeriFlux is a network of scientists who make micrometeorological measurements of ecosystems, forests, grasslands and agricultural crops in regions of the United States. There are similar networks all over the world, he said, collecting data and making their data available to the public.

"We're measuring the turbulent transfer of the species we're interested in, including carbon, water and other trace gases. We rapidly measure the changes in wind speed, water vapor density and carbon dioxide density. We measure these concentrations and wind speeds 10 times per second," he said. All of those data have been recorded and stored – data from 17 years, 10 times per second, from three sites.

"We can combine those data with remote sensing data and look at the relationship between the signals the remote sensing sensor is detecting, and relate that to the fluxes we're measuring on the ground," he explained.

Suyker said scientists now have quantified the amount of carbon that has been sequestered by the agricultural ecosystems and have learned how much water vapor is leaving the ecosystems.

"We also are measuring the quality and quantity of light and how the ecosystems use available light, water and carbon, and how carbon is distributed in the components of the plant – the roots, the stalks, the seed," he explained.

Even a few years ago, it wouldn't have been possible to get the kind of information that Suyker and his colleagues now can obtain. They learn how ecosystems are functioning and how they respond to a changing environment – changing light, air and soil moisture.

"There is so much more to learn – not just one type of ecosystem, or one type of field, but on a regional basis, on a continental basis. It is going to lead to even better science," Suyker said.

Suyker and other scientists combine their research data to learn more about the physical process in the agricultural ecosystems. The measurements of photosynthesis and transpiration can help in developing new models, help improve the accuracy of models and improve how models react to different stresses that plants and plant canopies experience, he said. This provides data for remote sensing studies that examine radiative vegetation indices related to measurements on the ground.

"The scale of our measurements is typically the size of a single field, but with remote sensing, we can get data from a large area. We can relate what's happening from that field and relate it to other fields, other parts of the country and other parts of the world. Then, we can start to develop global budgets of carbon dioxide and evapotranspiration," he said.

Suyker collaborates with scientists in other disciplines, such as agronomy and soil science. He also works with scientists in the Center for Advanced Land Management Information Technologies (CALMIT) in the university's School of Natural Resources. Scientists are looking at a number of different phenomena, he said; one is fluorescence.

Fluorescence is when the plants are using some of the light to photosynthesize; they're also emitting some of the light, and that is detectable by very sensitive sensors. Fluorescence is a direct indication of the photosynthesis occurring in the plant, Suyker said. New technologies are on the horizon, such as new satellites that will be able to detect fluorescence from space.

Interview with Mark Svoboda
By Cassandra Huck

NATIONAL DROUGHT MITIGATION CENTER

Monitoring, planning, preparing for drought.

When comparing the climates of eastern and western Nebraska, some may find it hard to believe one state is capable of such variation. Residents in eastern Nebraska expect snow-driven winters and wet springs with close to 40 inches of precipitation each year. In contrast, western Nebraska residents see less than 15 inches of precipitation each year.

Differences aside, Nebraska sets the stage when it comes to climate research, and its drought research and preparedness tools help people around the world.

Mark Svoboda is director of the National Drought Mitigation Center at the University of Nebraska–Lincoln and said drought mitigation refers to the steps taken prior to a drought to lessen the impacts of the hazard. The center was formed in 1995 with the goal of helping people reduce the hardships that come with drought. The center focuses on three areas:

- Policy and planning;
- Drought monitoring and early warning; and
- Conducting risk and vulnerability assessments.

According to Svoboda, the National Drought Mitigation Center serves anyone who needs information about drought. Half of the center's staff comprises physical scientists, including hydrologists and climatologists, while the other half of the staff is social scientists who spend a lot of their time working directly with people.

"You don't want to be reacting to drought when you're in the middle of the crisis; that is the absolute worst time to deal with the drought. Our job is to help translate science on drought to the media and to the public, such as decision-makers and policymakers, to help them make better-informed decisions," Svoboda said.

When the National Drought Mitigation Center began, there were just a dozen or so states that had drought plans. Now 47 states have drought plans.

But it isn't only Nebraska and the United States that benefit; Svoboda said the National Drought Mitigation scientists have worked with more than 75 countries around the world on projects, workshops and on technology transfer and capacity-building.

"It is working with a country to build capacity, maybe help build an early-warning system or help them develop a drought plan. That drought risk management system is the one we're working on with partners in the Middle East and north Africa through funding from the United States Agency for International Development," Svoboda said.

SAME SECTOR, DIFFERENT DEFINITION

"Everyone's going to have their own definition of drought. For me, it's when you don't have enough water to meet a need, whatever that need is," Svoboda said. Farmers who irrigate their crops may focus on groundwater availability, while farmers in a rain-fed area may relate their definition to the yearly rainfall average. Homeowners may focus on water coming from the tap, while a business may judge water quantity based on the requirements of the specific business.

"There's no one definition of drought, so we have to be very flexible and work with folks to plan for what drought is to them. We have to tailor and package our tools so they are flexible enough to meet their needs and we do that by engaging them throughout the entire process, from the very beginning to the very end and even beyond," he said.

Drought can affect many different sectors, ranging from farming to health. When drought begins affecting operations that have been in families for generations, it can have a serious impact on mental health. According to Svoboda, the National Drought Mitigation Center has been working with the Centers for Disease Control and Prevention to bring attention to physical and mental health issues caused by the stresses of drought.

Drought also can affect the water supply for hydropower, which is water runoff in rivers being used to generate electricity.

Svoboda said scientists in the center determine an area of drought by looking at many factors, including rainfall deficit, higher-than-normal temperatures, vegetation stress from satellites, soil moisture, evapotranspiration, stream flows, groundwater, and snowpack in the west, where much of Nebraska's water originates.

"We're trying to assess and utilize any data we can find that measures the climate or hydrology of an area, then we can rank them historically and determine what defines a drought in a region in terms of frequency and severity," he said. Droughts behave uniquely across the various seasons and within different regions of the state and the country, he added.

"We work with folks to plan for what drought is to them, and package our tools so that they're flexible enough to meet their needs," Svoboda said. Those tools include planning, data collection and monitoring, early warning, risk assessment and preparing a plan – even infrastructure, Svoboda said.

Drought needs to be given more attention than most other hazards, because droughts can last longer and cover larger areas compared with other hazards, he added. Drought can also impact sectors like tourism and other businesses, so the center's scientists are prepared to address all of these potential impacts.

MAINTAINING, TRANSLATING DATA

A variety of hardware and software tools measure virtually every component of climate, every minute of every day. The National Drought Mitigation Center gathers the data, stores it, analyzes it and makes assessments based on the sum of all the data, then makes it available to the public.

"Everything we do is in the public domain," Svoboda said. "We make all of our data freely available." A team at the National Drought Mitigation Center is dedicated to ensuring that the geospatial data and web mapping services are working properly and that data is readily available for public consumption.

University collaborations include the Holland Computing Center, which provides supercomputing services, the Center for Advanced Land Management Information Technologies (CALMIT), which is the university's remote sensing center, and the Daugherty Water for Food Global Institute, which was established to combine the university's expertise to address water use and management in agriculture. These groups work together to provide and maintain the data and derivative products and services needed to prepare for droughts around the world.

U.S. DROUGHT MONITOR

On average, droughts rank on par with hurricanes for the "most economic loss per hazard event" in the United States, Svoboda said. Droughts can last a long time, cover a large area and impact millions of people in various sectors. They can be widespread and lead to large economic losses. In response, Svoboda co-founded the U.S. Drought Monitor in the late 1990s as a partnership of the National Drought Mitigation Center, the U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA). Several state and federal government agencies, such as the USDA Farm Service Agency and the Internal Revenue Service, rely upon the drought monitor map when it is published each Thursday.

"We've never not met the deadline of Thursday morning so that's a good record to keep. And we rely on our partners here at the university to help us maintain the network," Svoboda said.

The U.S. Drought Monitor categorizes drought severity on a scale from D0 to D4 with D0 being abnormally dry and D4 being an exceptional drought, Svoboda said. Learning from the Fujita scale, which rates tornado intensity, and the Saffir-Simpson Hurricane Wind Scale, Svoboda said he intended to keep the U.S. Drought Monitor simple. The 2002 drought was the first turning point for the U.S. Drought Monitor, he said. Now, it is being used by the U.S. Department of Agriculture and several other entities throughout the United States.

RESEARCHING TO PREPARE

According to Svoboda, determining an area of drought is based on numerous conditions. One is looking at the basic hydrologic cycle of rainfall. From there, researchers look for rainfall and soil moisture deficits and above-normal temperatures that may worsen the lack of precipitation. Another condition is based on the supply of stream flows, groundwater and snow pack in the western part of the United States. The goal is to obtain as much data as possible to measure the hydrology of an area and rank that based on previous years. From there, it's determined whether it occurs frequently, on average or infrequently. Drought differs in different seasons and in different regions of the country, even within the state of Nebraska, he said.

To learn more about the National Drought Mitigation Center, visit www.drought.unl.edu.

Interview with Brian Wardlow
By Aliesha Dethlefs

OBSERVING THE WORLD FROM ABOVE

Satellites, planes, unmanned aerial vehicles

Predictions of drought, famine and other disasters don't happen based on someone's ability to foresee the future. They depend on science and leading-edge technologies, such as those used in the Center for Advanced Land Management Information Technologies (CALMIT) at the University of Nebraska–Lincoln.

Those leading-edge technologies include remote sensing, using digital imagery collected by satellites, airplanes and unmanned aerial vehicles (UAV) to assess agriculture, natural resources, natural disasters and climate events that affect land and people around the world. These different types of digital imagery comprise massive amounts of data, which are analyzed using various models to convert these data into valuable information that map and monitor the changing world with practical applications by both the public and private sectors.

Brian Wardlow is director of CALMIT and associate professor in the university's School of Natural Resources.

"There is a lot of pressure on natural resources in terms of sustainability and making them more resilient to either the growing population or to various environmental stresses. Remote sensing provides us a key tool that complements methods in the traditional toolkit – which normally relies on ground-based methods – to allow us to look at things at multiple spatial scales ranging from individual fields to countries and continents and even the entire Earth," Wardlow said.

Remote sensing observations are used to look at vegetation health or stress, and soil moisture conditions. Scientists also use this technology to look at evapotranspiration, which equates to the consumption of water by plants and how that might change.

"We're capable of looking at atmospheric and land conditions and the different dimensions of the hydrologic cycle from the satellite, which include precipitation, soil moisture, evapotranspiration and plant vigor to understand where drought might be emerging and changing – and what is the impact," he said.

The impact on agriculture, natural resources and ecosystems services is important, but beyond that is the impact on policymakers and decision-makers, he said. Government agencies might use it to develop a disaster declaration; international organizations might use the science to determine food security issues.

They may use that information to decide where to place resources, or highlight locations of an emerging food crisis or a famine based on various types of climate or crop condition information developed from remotely sensed image data, he said.

CALMIT was originally founded as the Nebraska Remote Sensing Center in 1972, at the beginning of the satellite-based remote sensing era, to explore how space-based observations of the Earth might be used for agricultural purposes. It was later renamed the Center for Advanced Land Management Information Technologies, or CALMIT. The name reflects the rapid expansion of other spatial tools in addition to the remote sensing commonly used today in agriculture and natural resource management that include geographic information systems (GIS) and global positioning system (GPS) technology, Wardlow said. Nebraska is one of several centers across the country focused on application development of remote sensing and other spatial technologies in these areas, but is one of the few that can pursue research and applications at various geographic scales using a suite of image observations collected from field-based systems, UAVs, airplanes and satellites.

CALMIT scientists conduct basic research into understanding the remote-sensing signal and how it relates to the environmental conditions at a specific point on the ground. The findings from that research are applied in a practical way, to benefit those who need or want the information to help solve real-world issues related to agriculture and water resource management, such as crop stress identification and irrigation scheduling.

REMOTE SENSING WITH SATELLITES, AIRPLANES, UAVS

Remote sensing can be used in many areas within and outside of natural resources, Wardlow said. Satellites, airplanes and UAVs all can be used to accurately monitor specific points of interest on the ground. Sensors are tailored to study the land, oceans and atmosphere and allow researchers to look at vast areas that they cannot visit every day or that might be inaccessible for a variety of reasons.

"Satellites give us observations ranging from individual fields, to the entire state, to the entire world in one snapshot," Wardlow said. "We can identify what crop or feature is on the landscape and also assess something about its state or condition and how it might change." Imagery acquired by airplanes and UAVs provides detailed views of more local landscape and often supports site-specific management activities such as precision agriculture.

BIG DATA AND REMOTE SENSING

Sensing technologies generate large amounts of data that, when analyzed, help scientists and other decision-makers better understand and manage natural resources and learn about processes that could be impacting the environment. Over the past decade, remote sensing began generating more data through the use of sensors and sensors mounted on UAVs and planes. This practice has allowed researchers to look at more than one component when evaluating an area and provide the detailed, site-specific information at a spatial scale useful for land managers, Wardlow said.

"Instead of just vegetation health, which was the primary application of remote sensing a decade ago, we can now learn about soil moisture conditions and plant water consumption rates through evapotranspiration estimates. We can also look at groundwater using certain sensors that we were not able to do before. It has been a true innovation and has rapidly placed remote sensing technology and information in the hands of the general public," he said.

People increasingly understand that remote sensing is because of Google Earth and imagery now being collected by UAVs, Wardlow said. The emerging and improving UAV industry has opened new areas in remote sensing, making it more accessible for public interaction in the technology arena.

The large data sets generated through the sensors have required new algorithms and advanced computing methods, combining the data in unique ways to study more complex environmental and natural resource questions, he added. Data is collected and processed, then must be corrected for factors such as atmospheric conditions, to get a clearer view of Earth's surface, Wardlow said.

CONNECTIONS, THE FUTURE

Wardlow connects with other remote-sensing scientists throughout the world who are doing innovative research, especially in drought monitoring. They work together to integrate new remote sensing information into drought-related decision-making processes, hoping to get decision-makers to use the information in practical ways.

"We can look at the interconnectedness of the environment within natural resource management and sustainability at different spatial scales, and in new ways and over larger areas, that we couldn't before," he said.

Remote sensing also has the potential to play a critical role in terms of food security issues, including natural resource and water resource sustainability and early reporting of impending disasters like droughts, Wardlow said. That early reporting can give nongovernmental organizations time to move food supplies or people to minimize the impact.

University research of crop phenotyping focuses on development on crop varieties that are more tolerant of extreme weather conditions – one tool scientists can use to address food security issues. Remote sensing is playing a critical role in the phenotyping effort as university faculty are relating the remote sensing signal to different crop traits to better select new, more productive and stress-tolerant varieties. Remote sensing also can be used to see what may be happening across a country's borders, he added – such as political issues that result in inaccurate reporting of crop yields.

"To me, a successful remote sensing project is the practical application and that's the point where we try to make it publically available in an easy way to improve real-world decision-making in agriculture and natural resources," Wardlow said.

For more information about CALMIT, visit calmit.unl.edu.

“There is a lot of pressure on natural resources in terms of sustainability and making them more resilient to either the growing population or to various environmental stresses.”

Brian Wardlow

PEOPLE

"One important piece of our findings is the nature of how people view their world depending on the size of community they live in. This is a question that comes up in economic development and community development all the time."

Randy Cantrell

Interview with Andrew Benson
By Victoria Talcott

SIMPLE GOAL: CURE DISEASE

Nebraska Food for Health Center scientists collaborative, determined.

Research into the intestinal tract – "the gut" – has shown that the hundreds of trillions of microorganisms living there influence the development of gut tissues and the immune system and affect organ function and metabolic function. There is recent evidence that those trillions of organisms may also influence a person's behavior, suggesting a relationship between the gut and the brain.

Andy Benson is director of the Nebraska Food for Health Center at the University of Nebraska, a $40 million multidisciplinary initiative combining agriculture, health and medicine with a goal of improving human health through diet. Benson is the Food for Health Presidential Chair and a professor in the University of Nebraska–Lincoln Department of Food Science and Technology.

The center's research is expected to impact diseases such as inflammatory bowel disease, cancers, and metabolic diseases such as diabetes and obesity. Studies of those diseases show that the collection of microorganisms, called the microbiome, is functioning abnormally, he said, although it is still unclear if the abnormalities actually have a causal relationship to these diseases or are a consequence of the diseases.

STRAIGHTFORWARD MISSION

The main mission of the Nebraska Food for Health Center is to develop the science of dietary modulation of the gut microbiome – to fully understand how components in food influence the microbiome and to design foods that are clinically proven to promote beneficial configurations of the microbiome in individuals. A second mission is to train the next-generation workforce to work across disciplines and commercialize products that can aid in human health.

"Some of the diseases we're talking about are horrible. They have huge impacts on individuals and their quality of life. Just imagine having an entirely new approach to preventing or treating these diseases, simply by dietary modification. That's a game changer," he said. "That's the type of transformative impact we can have on these diseases."

Benson said he and the other scientists on the Food for Health team are focusing on a few diseases initially, including complex diseases such as Inflammatory Bowel Disease (IBD) and genetic diseases such as Cystic Fibrosis (CF). While CF is caused by mutations in a single gene, there are over 200 different genes that are known to contribute to IBD. Thus, the genetic base for these diseases is very different.

"It has already been established that the gut microbiome and the lung microbiome are abnormal in CF patients, and we believe these abnormalities may be more uniform in CF patients because of the common genetic cause. On the other hand, the abnormalities in the microbiome of IBD patients are highly diverse, reflecting the broad genetic base of the disease," he explained.

Benson believes it could be easier to "learn" how to modulate the gut microbiome of CF patients with dietary components, and then use those principles to develop dietary modulation strategies in more complex diseases such as IBD. Whether a genetic disease or a complex disease, most of these diseases dramatically affect life span and quality of life.

"You can't fix the genetic defect, but just imagine if you will be able to extend the quality of life with dietary modulation – it's an entirely different approach to thinking about medicine," Benson said.

Examples of "functional foods" that can function as dietary modulators of the gut microbiome include resistant starches and galacto-oligosaccharides (GOS). Resistant starches are insoluble dietary fiber products that are found in whole grains, beans and peas. Galacto-oligosaccharides are naturally occurring, complex carbohydrates that can be found in some plants and they can be used as prebiotics.

There are five-year and 10-year goals for the center, he said; the five-year goal is to switch from a domestic focus to a global focus. The 10-year goal is to use food to intervene in some of the most difficult global challenges, such as children's growth and neurocognitive development and their ability to respond to vaccines, both of which are believed to have some relationship to nutrient-poor diets.

PLANTS, THE GUT, CHEMISTRY – AND DATA

The Nebraska Food for Health Center brings together scientists from other campuses, centers and departments of the University of Nebraska system, providing expertise and research infrastructure that form the scientific backbone of the center's work, Benson explained. Scientists are studying plant genetics, biology, neuroscience, immunology, medicine, food science, statistics, computational biology, and more.

"These faculty members are rock stars on their own. Everybody bought into the vision because they can clearly see how transformative this is going to be and how their expertise connects to the mission," he said.

Plant genetics are part of the Center for Plant Science and Innovation (CPSI) and is a critical part of the Nebraska Food for Health Center.

"NFHC chose plants as a primary commodity on which to focus our dietary modulation theme because of the tremendous expertise that exists in CPSI and the immense varieties of crop plants developed by the plant breeders. Among the thousands of highly diverse varieties of maize, soybean, sorghum, and common bean that have been developed, none of them have ever been screened for the ability to modulate the human gut microbiome. When you combine the plant expertise with the gut function group — the group from which the Nebraska Food for Health Center evolved — and you connect that with the powerful expertise in bioinformatics and biostatistics, and the animal model systems available at the University of Nebraska–Lincoln and the University of Nebraska at Omaha, you have a very powerful engine for discovery and translation," Benson said.

Benson said the center's research generates large, complex datasets. The data requires specialized computational skills for processing and analysis, so the Nebraska Food for Health Center collaborates with programmers, statisticians and algorithm developers, as well as with the Holland Computing Center.

"We couldn't do anything without the Holland Computing Center – the supercomputers," Benson said. The Holland Computing Center has the fastest computing resources in Nebraska and has two locations: one at the University of Nebraska–Lincoln's Schorr Center and the other at the Peter Kiewit Institute at the University of Nebraska at Omaha.

"Our data are extraordinarily complex, high-dimensionality and often, we're combining multiple types of data," Benson said, noting that the team will ultimately be combining microbiome data with clinical data, dietary data, and other measurements such as body composition from hundreds to as many as 1,000 individuals. "Data drives a lot of what we do," he added.

The Department of Food Science and Technology moved to Nebraska Innovation Campus in 2015, along with its Food Processing Center and pilot plants, to a complex called the Food Innovation Center. In addition to laboratories, the Food Processing Center offers the faculty and facilities for developing new foods, and harvesting of ingredients from plant materials that could be incorporated into foods, Benson said. There also is a human clinical facility in the Food Innovation Center, Benson said, in which scientists can conduct dietary modulation studies with human volunteers.

"It's amazing to have that capacity there," Benson said.

BACKGROUND

Benson is a microbial geneticist by academic training who spent the first 15 years of his university career conducting research to understand how the genomes of food safety organisms are evolving and how that impacts their transmission patterns in foods. He also teaches food microbiology classes for undergraduate and graduate students in the Department of Food Science and Technology. The human genome was sequenced in the late 20th century, accelerating scientific discoveries in human health. The commercialization of DNA sequencing occurred in 2006.

"It became clear that we were going to have the capacity to actually study the hundreds of trillions of organisms in the gastrointestinal tract, which was something we'd dreamed about doing as microbiologists," he said.

"We established the Gut Function Initiative in 2007 and by 2008, were studying multiple aspects of the gut microbiome," he said. The Gut Function Initiative had three goals: to understand the host factors; the microbial factors; and the dietary factors that influence how the gut ecosystem functions. They learned that diet has a major role in shaping the microbiome.

Our focus on dietary modulation emerged from that research. "It has the biggest impact on the composition of the microbiome and is something we can use in a beneficial way," he said.

It was the success of the Gut Function Initiative that formed the groundwork for the Nebraska Food for Health Center. Archie Clutter, dean of the university's Agricultural Research Division, approached Benson and suggested he develop a Program of Excellence proposal around food for health. "Dietary modulation of the gut microbiome is a way to unite agriculture and medicine. That's only going to happen at a place like the University of Nebraska," Benson explained.

Funding was discussed and native Nebraskan Jeff Raikes, co-founder of the Raikes Foundation and former CEO of the Gates Foundation and president of Microsoft's business division, expressed interest in helping to fund a food for health center. The University of Nebraska central administration supported the program of excellence and provided seed funding, while the University of Nebraska Foundation raised the rest of the funding.

"It's a really neat story of the planets aligning," Benson said

Interview with Janos Zempleni
By Bryce Doeschot

'TINY MESSENGERS ORCHESTRATE METABOLISM'

Nebraska Center for Obesity Prevention and Dietary Molecules focuses on science of human health.

Each time a person takes a drink of milk or a bite of food, nanoparticles – known as exosomes – within the milk or food deliver signals to different tissues in the human body that can turn genes on and off during the body's normal metabolic function. The result of this gene activity can lead to life-changing diseases, but scientists are learning to change the effect of the exosomes and hopefully, prevent human disease.

Janos Zempleni, Willa Cather Professor of Molecular Nutrition in the Department of Nutrition and Health Sciences at the University of Nebraska–Lincoln, also is director of the Nebraska Center for Obesity Prevention and Dietary Molecules (NPOD). Zempleni and a team of more than 50 university researchers work with nutrigenomics and computational sciences to solve complex problems by studying exosomes in food.

The objective of NPOD is to prevent obesity-related diseases, Zempleni said, by finding answers to complex questions about the human body. The current research focus areas are non-alcoholic fatty liver disease, heart disease, obesity and nutrient signaling.

The center, which began in 2014 with an $11.3 million grant funded by National Institutes of Health, is located at the university and collaborates with the University of Nebraska Medical Center.

Long-term, Zempleni would like to develop consumer-friendly pathways that improve health, without major disruptions in people's lives. He expects the university and NPOD to become a leader in nutrient signaling, controlling the genes that affect disease.

COMPLEX RESEARCH

Exosomes are nanoparticles that are not visible to the eye. One exosome contains as many as 10,000 different compounds. The exosomes are found in foods, including liquids such as milk. They control how tissues communicate with each other. The NPOD research team studies exosomes to find answers to complex problems within the human body, detecting diseases such as cancer.

"The exosomes deliver these signals to all kinds of tissues in our bodies and turn on and turn off genes," Zempleni said. "They're tiny messengers that orchestrate the metabolism. They regulate all 25,000 genes that a human has, and they affect different tissues in different ways."

Zempleni said one research project involved animal feeding studies, looking at excessive intake or depletion of exosomes in the animals' diet. One of the changes was in the DNA building blocks produced in animals. The team began studying the diets of human babies to determine what effect the animals' diet had on the infants.

"We observed that breast milk versus cow's milk formula versus soy formula had very different levels of exosome cargoes, which would have major implications for infants fed formulas," Zempleni said. A study was begun that collected urine samples from equal numbers of infants consuming breast milk, cow's milk formula and soy formula. Although the study is still being conducted, Zempleni said there is a different pattern of DNA building blocks in the urine of the infants fed cow's milk or soy formula versus the pattern of breastfed infants. "This is one of the examples where animal studies actually translate nicely into human research," he added.

DATA COLLABORATIONS

One of the many challenges of exosome research is that it generates huge data sets, Zempleni said, and these large data sets must be analyzed. "There has been a spike in data generation, of big data in our lab because of all the exosome work and the thousands of genes that these exosomes affect," he said.

Zempleni defines "big data" as anything that requires more than a desktop or laptop computer for processing the data.

"The data sets are huge. We generate the data in the lab in collaboration with biochemistry or other institutions in the United States," Zempleni said. The data becomes such a large part of the laboratory that students and staff are dedicated to handling the data.

Zempleni and his research team build computational expertise within their research group by including graduate students with strengths in data analysis, as well as collaborators from other departments. Juan Cui, an assistant professor in the Department of Computer Science and Engineering, is such a collaborator. Cui's research is in understanding human disease through data integration and computer modelling.

"We create this data and ask all the biology questions, and then Dr. Cui comes in and applies her magic – does the analysis of the data – and she comes up with system solutions," Zempleni said.

SOLUTIONS

"People can no longer spend their entire research career looking at one single pathway," Zempleni said. Now, there are complex systems and patterns that have created a whole-systems approach. He believes that is where data science has advanced the field of biology.

"We are trying to change the way biologists work with computational scientists or data specialists," Zempleni said. "In reality, we still talk a different language: they 'talk computer,' we 'talk biology.' Sometimes it's impossible to really understand what the other party is talking about and that is one of the things we want to solve." In the case of the NPOD group, Zempleni arranges joint lab meetings so the computational partners learn about biology and the biology partners learn about computer data analysis.

HEALTHIER FOOD

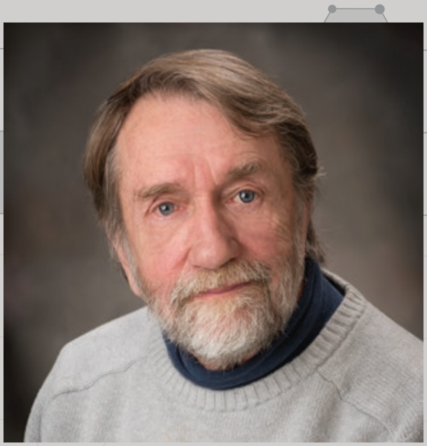
By understanding the research on exosomes and DNA makeup, Zempleni and his team research ways to make food healthier for people, to the point that using food for medicine can be part of the future.

Zempleni is not a big believer in dietary supplements, especially when it comes to supplements for individual nutrients. Many of these supplements cannot be used by the body, he said, because they are above the limit of what a person can absorb. Instead, Zempleni says that a balanced nutrition has major impact on a healthy lifestyle and disease prevention.

Beyond consumer choice, researchers at the center can begin to change the way food is composed to make it healthier.

Although it is possible to change the nutrient composition, Zempleni says that switching from saturated fatty acid, like butter, to olive oils can make dramatic differences in a person's health. "It's not about the amount of fat you consume, but the type of fat that you consume," Zempleni said. "We can tweak the pathways in plants or in animals to actually produce more of these healthy fatty acids," Zempleni said.

"We can tweak the nutrient composition in foods to make them healthier," Zempleni said. "That's really the future – this breeding for biomedical traits."



Interview with Randy Cantrell
By Jayde Olson

POPULAR MYTHOLOGY OF RURAL NEBRASKA – DEBUNKED

The Nebraska Rural Poll has annually gathered the aggregated voice of rural Nebraskans and relayed its findings to state and local lawmakers to ensure the rural voice is heard. The poll results are used by local policymakers and development groups to determine how they might be able to generate public interest in what they are trying to accomplish, according to Randy Cantrell, Extension professor with the University of Nebraska Rural Futures Institute and community development specialist.

ORIGIN OF THE RURAL POLL

The 2017 Nebraska Rural Poll survey was mailed out to 6,000 nonmetropolitan Nebraska households in March, to gather a collection of data about rural trends and perceptions. The poll is designed to present opportunities for people to work together to develop a vision for invigorating rural communities, Cantrell said.

The Nebraska Rural Poll has been mailed every year since 1996 and is the largest and oldest annual survey of its kind in the nation. It had its origins with the Center for Rural Revitalization and Development, which is housed within the University of Nebraska–Lincoln Department of Agricultural Economics. As part of an arrangement with the Rural Research Policy Institute (RRPI), the Nebraska Rural Poll was originally a collaboration between Iowa, Missouri, Minnesota and for a while, Arkansas. As part of this collaboration, they all agreed to do a sample survey of opinion of rural Nebraskans.

The annual poll questions are composed by a committee of faculty members from the Department of Agricultural Economics, the Rural

Futures Institute and the Department of Agricultural Leadership, Education and Communication, Cantrell said. The poll also routinely involves individuals with specialized expertise in assisting to develop the survey and analyze the results.

CONCEPTS

In the Nebraska Rural Poll's first year, survey data was summarized in four reports, which dealt with work patterns and benefits, state and federal taxes, environmental issues and the quality of life in rural communities. The reporting pattern of one quality-of-life report and three topical reports has been more or less repeated over the past 20 years.

Approximately 2,500 surveys are returned each year, allowing the poll to make statements at a 95 percent confidence level for Nebraska's nonmetropolitan population and for five broadly defined regions of the state, according to Cantrell.

Every year since 1996 the poll has asked a series of identical questions dealing with the concept of satisfaction with community amenities and attributes. These same questions are asked year after year so the Nebraska Rural Poll team can get a pulse of rural Nebraskans' opinions.

The concept of satisfaction is reflected in significant events, such as the 2008 recession. That year, Cantrell said he was able to discern changes in responses related to confidence in the future, income, job security and potential of finding a better job.

VALUE OF THE DATA

The Nebraska Rural Poll has provided reports on development strategies, immigration, technology, schools, business transfers, government services, climate change, water quality and quantity, animal welfare, housing, crime and safety, among others, Cantrell said. Poll responses have been of interest to policymakers, planners and development groups, according to a consortium of researchers in the Department of Agricultural Economics.

The Nebraska Rural Poll Team has been asked to testify before Nebraska Unicameral committees regarding opinions that are expressed in the poll. Local policymakers use the poll results when deciding what main issues to focus on concerning health care and education systems, according to Cantrell.

The poll results are distributed to members of the Nebraska Legislature, the state's congressional delegation, and other state and local leaders. They also are used by development groups to get a better idea about how people perceive the quality of housing in their communities, including cost and availability.

The Nebraska Rural Poll survey has collected a total of 57,000 observations from 1996. According to Cantrell, the Nebraska Rural Poll represents 17 percent of all the households over time. Therefore, the poll team now has the ability to look at all the data collected over time to look at changes that result from events that occur from the outside, such as the great recession or major weather events.

Cantrell said rural Nebraskans self-identify as being economically, politically and socially conservative in their views, according to the October 5, 2016, article titled "Poll: Rural Nebraskans Satisfaction," published by the Nebraska Rural Poll. Most also rated their city or town as friendly, trusting and supportive. Community size impacts rural Nebraskans' views, according to the article. Residents of larger cities are more likely than residents of smaller towns to say their community has improved during the past year and they are more likely to be optimistic about its future. They also are more likely than residents of smaller towns to disagree that their community is powerless to control its own future. However, residents of smaller towns are more likely to say it would be difficult to leave.

"The reality is when you add all rural Nebraska citizens' opinions together, they're considering things, they are not just making knee-jerk political statements every time you ask them a question," Cantrell said.

"The Nebraska Rural Poll debunks mythology about what rural people and their communities are like. That existing mythology about rural Nebraska is giving us a narrative of rural life that is just not correct and is very over-simplified. Therefore, our goal is to change the narrative and the Nebraska Rural Poll contributes to that," Cantrell added.

DATA INTERPRETATIONS

According to Cantrell, the poll team has a measure of five levels of satisfaction within each size of community for questioning the extent to which respondents are "satisfied" with various aspects of their lives and their communities. In this context, satisfaction is defined as "the fulfillment of a need or want."

The four sizes of Nebraska counties measured are:

- Micropolitan (contains a core urban area of at least 10,000, but less than 50,000 population)
- Core counties, counties with a trade center larger than 2,500 residents;

- Counties with no trade center that large; and
- Counties with no such trade center and with population densities of fewer than six per square mile.

The data results collected from the poll demonstrate that there is very little variation in satisfaction with one's community to be found across the four categories of community size, according to Cantrell.

The samples from the Nebraska Rural Poll results are large enough that they are statistically significant, Cantrell said. The data is then used for interpretative analyses in which a theory is created after close observation.

Nonmetropolitan Nebraskans tend to be satisfied with where they are, even if the resources available in that location are limited. The Rural Poll has repeatedly demonstrated that, while satisfaction with consumer products (e.g., restaurants, retail and entertainment) tends to be higher in more urbanized locations that offer more variety, satisfaction with social relationships (e.g., friends and neighbors) tends to be higher in more rural locations. This information was published by the Department of Agricultural Economics in the December 7, 2016 article, "Does Community Size Affect Resident Satisfaction? Data from the Nebraska Rural Poll."

"One important piece of our findings is the nature of how people view their world depending on the size of community they live in. This is a question that comes up in economic development and community development all the time," Cantrell said.

"I've learned a lot from the Nebraska Rural Poll in terms of the difference that exists between the popular mythology of what modern Midwestern people are like and the reality of what they're like. I love being able to demonstrate that," Cantrell added.

Interview with Melanie Downs
By Shelby Andersen

A MATTER OF LIFE AND DEATH

Food allergy research focuses on identifying allergens in food products.

For people with severe food allergies, even a trace can cause illness … even death.

That's why the work of the five scientists in the Food Allergy Research and Resource Program at the University of Nebraska–Lincoln is so important. Scientists like Melanie Downs, assistant professor of food science and technology, are working toward understanding and identifying allergenic proteins, which can create safer food manufacturing processes and safer food products.

"There are several studies about how much a food allergy impacts quality of life," Downs said. "There is a lot of anxiety when it comes to something that the rest of us take for granted," she added. Even community interactions that surround food can be frightening – even prohibitive – for people with food allergies.

Allergens are molecules that the human immune system attacks for reasons scientists don't yet understand. According to Downs, a food allergy is caused by proteins in nearly all cases. The discipline that studies proteins on a large scale and in complex systems is called proteomics.

The Food Allergy Research and Resource Program (FARRP) is a partnership between the university and more than 90 food companies. Its missions are to develop and provide the food industry and the agricultural biotechnology industry with credible information, expert opinions, tools and services relating to allergenic foods, novel foods and food ingredients, including genetically modified food products.

NEW TOOLS IN ALLERGEN DETECTION

Downs said FARRP scientists are developing new methods that better detect proteins and give consumers confidence about whether there are allergens in food products.

One area that produces large amounts of data is proteomics research, specifically protein mass spectrometry experiments, Downs said. This gives scientists the ability to look at sizes and sequences of peptides from proteins in a sample, then match those back to protein sequences in a database.

"Proteomics is a bit newer than genomics, so we're still developing a lot of the tools and statistical methods to do the protein identification process and matching what is observed in a sample to what we know from databases about protein identifications," Downs said. "Because of the tools we have, like mass spectrometry, we can now look at, in theory, all of the proteins in a biological sample," she explained.

Much of the research is focused on food allergen management by the food industry to be sure that there isn't an unintended presence of an allergenic food or proteins from an allergenic food in another food product, Downs said. This accidental cross-contact can cause food safety concerns for allergic individuals. Her work with FARRP provides a direct connection to the food industry and its manufacturing processes.

Scientists conduct frequent training workshops for, and answer questions from the food industry, ranging from specific allergen information to monitoring suppliers' products, to regulations governing the food industry. They also help manufacturers with food allergen safety processing procedures, Downs said.

WHAT ARE ALLERGENS?

The eight most common food allergens, called the "Big-8," are milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, wheat and soybean, Downs said. These foods account for about 90 percent of all food allergies in the United States and must be declared on the labels of processed foods.

Downs' research is improving methods of identifying allergens in processed foods. If traces of allergens are detected, a manufacturing facility must revise its processing, cleaning and ingredient segregation protocols. Current testing can be as simple as a "dipstick" test that is used often in food production facilities, to laboratory-conducted enzyme-linked immunosorbent assay (ELISA) testing that is sensitive and protein-specific. A polymerase chain reaction (PCR) test that identifies DNA, but not proteins, can be used as a second confirmation if there are questions about results, Downs said.

Downs said she and other FARRP scientists work with food manufacturers on efficient cleaning of manufacturing equipment and verification of cleanliness through accurate testing.

Protein mass spectrometry testing produces massive amounts of data that must be analyzed to answer questions about allergens. The collections of data can also be shared in repositories accessible to scientists all over the world. There, informatics specialists can obtain and "mine" the data for protein identification properties.

FOODS: SAFER FOR CONSUMERS

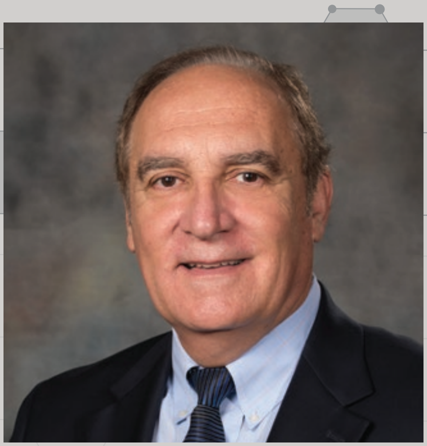
Processing of foods, including baking or frying, changes the nature of foods, Downs said, and also can change standard tests' abilities to detect proteins. "We're looking at developing new methods that might be able to detect those proteins better and give better confidence about whether there are allergens still present in the products," she said.

In some cases, food processors' protocols are more extensive than necessary, she said, so more accurate testing will help manufacturers to operate more efficiently.

Scientists in FARRP also help to create and update facilities' food safety plans. These plans include quality control from start to finish, she said, and include monitoring of suppliers, managing intake, scheduling production, cleaning equipment and managing traffic patterns, all to help ensure a safe product for consumers. These steps need to be validated with testing to be sure no undeclared food allergens are present, Downs said.

Downs said it is important that consumers know how much time the food industry spends managing food allergens, and that those management practices are well-validated with scientific, analytical data.

"I think the ultimate goals are to make food safer for food-allergic individuals, give them more selection in terms of their food choices and give them more confidence that the food products they are getting are safe," Downs said. "We want to improve their quality of life."



Interview with Theodore Lioutas
By Cassandra Huck

ADVANCING FOOD TRACEABILITY

Improving Consumer Safety

The rapidly increasing world population is on the mind of Theodore Lioutas, a research professor in the Department of Biological Systems Engineering at the University of Nebraska–Lincoln, as he considers an abundant and safe food supply for the future.

Basic challenges are food waste, food safety and consumer preferences.

"What people don't realize is that almost 48 percent of the food produced today is never eaten. It's basically wasted. It's staggering, and most people don't believe it," Lioutas said.

A wholesome and safe food supply is vital to the well-being of the country and communities around the world, he said, and that is a goal of the Transformational Food Manufacturing Innovation Institute (TFMII). The TFMII is a public-private partnership that includes manufacturers, development entities, the University of Nebraska–Lincoln, the University of California-Davis and the Georgia Institute of Technology. The TFMII is focused on advancing and automating the skills and technologies in the United States food and beverage industry in four areas: automation and control, sensors, big data, and antimicrobial materials and coatings.

The founding of the Transformational Food Manufacturing Innovation Institute was created in response to economic, production and safety concerns by researchers and manufacturers.

"We felt like the safety and security of the U.S. food supply was in jeopardy for the future, especially for the next 50 years," Lioutas said. Advances in food and medical science have improved the quality of life, he said, but in the last 50 years, the food industry hasn't addressed the upcoming needs of the world's growing population. Add to that, much of the world's food supply is handled by humans, who may cause contamination of food and cause foodborne illness and expensive product recalls.

Lioutas said in 2016, the USDA reported that 48 million people in the United States contracted a foodborne illness. "Usually about one-third of the cases are reported," he explained, which would mean that nearly half of the U.S. population got sick last year from food poisoning. Food poisoning is a term used to describe a foodborne microbiological concern or pathogen like Listeria or Salmonella, he said. Sometimes the bacteria affect the food in the supply chain, but often, bacterial contamination occurs at home, due to improper handling and storage of food by the consumer.

Consumers need to be educated by scientists and professionals about the dangers of mishandling food, and the industry needs to be educated by consumers regarding the new wants and demands. "It's a two-way street," Lioutas said.

TRANSFORMING FOOD

The food products consumers buy in a grocery store have gone through a series of transformations during processing, Lioutas said. Those processes usually are a collection of chemical, physical and engineering processes, such as heating, cooling, cutting and shaping. The food industry refers to this process either as food processing or food engineering – applying engineering, chemical and physical principles to food to transform it from the commodity form into a finished product that consumers want to buy and eat.

Some of the advanced manufacturing methods currently being used, or which will be used in the future, include automation and robotics, biohazard sensors that immediately detect bacterial pathogens in food production, data analytics, artificial intelligence and research into bacteria-resistant manufacturing surfaces. "These are fundamental science and engineering areas that scientists at TFMII will be studying," he said.

Lioutas believes the food industry will face additional challenges in the next few years; challenges like climate change, which could affect food production; the world population growth; the expansion or contraction of the global middle class; and demands of consumers. However, the scope of challenges must be overcome to provide a safe, consistent food supply.

CONSUMER INTERESTS

The idea to include "transformational" in TFMII came from the goal to transform the design of future food factories and how they operate. Consumers have new expectations that will require products to have shorter shelf lives, fewer preservatives and convenient packaging. Lioutas said the previous model of large manufacturing facilities that distribute over long distances is no longer going to be efficient. The industry is now looking at decentralizing manufacturing and moving facilities closer to population centers. This will help meet the needs of the consumers.

A recent consumer interest is the traceability of food, Lioutas said.

Food traceability tracks every ingredient from the farm, to the production facility, to the grocery store. It is a collection of data related to every component of food that consumers see, he said. Every ingredient, commodity, every part of the product's recipe has actual history – how each component was grown or raised, whether it is a protein or a plant, how it was processed, and whether fertilizers or other chemicals were used in production.

"The collection of all this data is 'traceability' and also is related to the microbiological safety status of the product," he said. When the consumers purchase products, they know their history.

Product history must be transferred through every part of the food supply chain as the product changes hands. The information should be readily available for consumers to view as they make buying decisions. According to Lioutas, the data needs to be transformed into consumer-usable metrics, such as a phone app that scans the product's barcode and displays the information about when the product was produced and how much shelf life remains.

"One thing we need to do is make sure that the farmers, the transporters, the manufacturers, the warehouses, the final product shippers and suppliers all have equipment, computers and language platforms that communicate with each other," Lioutas said.

For more information on the Transformational Food Manufacturing Innovation Institute, visit: http://engineering.unl.edu/tfmii/

Interview with Melanie Simpson
By Morgan Zumpfe

DISEASE ON THE MOLECULAR LEVEL

Using the smallest physical unit to find big answers.

About one in seven American men will be diagnosed with prostate cancer during his lifetime.

At the time she was interviewed for this story, Melanie Simpson was a Willa Cather Professor of Biochemistry at the University of Nebraska–Lincoln and director of the Molecular Mechanisms of Disease graduate program and co-director of the Complex Biosystems Ph.D. program. She now is head of the Department of Molecular and Structural Biochemistry at North Carolina State University.

Simpson's research goal is curing prostate cancer. The biochemical mechanisms she studies are applicable to breast cancer, too.

Every cancer starts with a cell in the body, Simpson said; it means that something happened to that cell; it isn't behaving like the other cells.

"We want to understand what has happened to the cell, what it's doing that allows it to behave like a cancer cell – to grow and to invade tissues and go to other places in the body. That's not what normal cells do," she said. Her research focus is centered on how tumor cells escape from the primary site of the prostate and get to other parts of the body, called metastasis.

One of her areas of research is the complex network of proteins that holds the body together; not just the bones and the skin, but the proteins that direct cells to stay in place and behave normally, she explained. If a tumor cell wants to become active, it has to reorganize the protein network.

In prostate cancer, Simpson and her team study mechanisms that rid the male body of excess steroid hormones in the prostate, which affects a prostate cancer treatment called hormone deprivation therapy, she said. When a man experiences a recurrence of prostate cancer, it's because the tumor cells have learned to make their own hormones, which they aren't supposed to do, Simpson said.

"That backup mechanism for excess steroid elimination is faulty, so we want to be able to control the backup mechanism to get it to turn back on again and prolong responsive therapy and maybe, prevent recurrence," she explained. Simpson and her team of research collaborators want to find a cure for cancer, but it's a long, complex process.

But there's hope.

"We have defined a specific protein pathway and used our knowledge of molecular details of a protein in that pathway to screen for new drugs. About 100 molecules we've found potentially control this pathway, so we're working through those one at a time. One of those small molecules could be the next drug administered at the same time as hormone therapy and may sustain the response or prevent recurrence," she explained.

The mechanisms and pathways Simpson studies pertain to cancer research, but also to stress responses.

"Believe it or not, there are even orthologs in plants," she said. An ortholog is a gene found in two or more species that have a common ancestor, so pathways in plants and agricultural animals can impact global challenges of stress responses, such as heat and drought, she explained.

"But cancer itself is a huge global problem, so even if our results were restricted only to the cancer system, we hope to be able to contribute, if not with a cure, then at least with insights that lead to better therapies," Simpson said.

Simpson is a biochemist, a cell biologist and a cancer biologist, but her goal of finding a cure for prostate cancer requires collaborations with other specialists. Collaborations with chemists are essential to synthesize new derivatives of small molecules so there can be better cancer-fighting drugs. Collaborations with medical doctors who specialize in urology and the treatment of prostate cancer provide specimens and samples, but also the human connections with patients. She also collaborates with biological systems engineers and with other types of biochemists – scientists who have expertise in understanding proteins as enzymes and the mechanisms of actions and can characterize inhibitors, she said.

"It's increasingly important to have collaborators who understand statistics and computational methods, because our data sets are getting bigger and the complexity of comparing data sets is increasing," Simpson said. A huge data set may yield a single molecule that is significant, and it is one of these individuals who can identify it and pull it from a pool of data, she said.

MEDICAL BREAKTHROUGHS VIA DATA

The future of data in medicine is "huge," Simpson said, citing breakthrough tumor evolution as an example. Researchers collect and biopsy specimens from the same small tumor, in the same person, and sequence all the DNA. Differences in the sequence can be identified within the same tumor, Simpson said, and can be traced back to the original cell and when that original cell changed.

"This is huge, breaking news, and tells us why we haven't had successful cures. Now we know we need to sequence those tumors close to the time of therapy, then sequence them again to make sure we're still treating the same tumor we were treating at the start," she explained.

Data sets associated with this breakthrough information are enormous, but the impact of collection and statistical analysis of the data lead to improved cancer treatments.

"We almost can't study cancer any longer without huge data sets," she said.

One of Simpson's most influential collaborators is Jennifer Clarke, director of the university's Quantitative Life Sciences Initiative and professor of food science and technology. Clarke's expertise is big data science and assists Simpson in analyzing the data for answers to Simpson's specific questions.

Simpson produces research data through samples and cell cultures and through advanced instrumentation, such as mass spectrometry, nuclear magnetic resonance spectroscopy and liquid chromatography. The statistical applications follow, to understand what is significant and what is not.

GRADUATE PROGRAMS

Simpson is director of the university's Molecular Mechanisms of Disease Graduate Training Program, an interdisciplinary graduate program involving seven academic departments in three colleges that bridges research programs. The focus, Simpson said, is to have students work together to understand disease mechanisms from different perspectives, including chemistry, engineering, animal science, biological systems engineering, chemical molecular engineering, chemistry, biological sciences, biochemistry and food science and technology.

"There are new labs collaborating that didn't previously know about the others," Simpson said, resulting in new collaborations, joint grant proposals and joint publications among investigators whose students bridged disciplines.

She also is director of the Complex Biosystems Ph.D. program, which is directed toward students interested in the statistical and computational approaches in multiple areas of the life sciences. The program is interdisciplinary and tailored to a student's specific interests and career goals.

OBLIGATION

Simpson's work is funded by the National Institutes of Health, the National Science Foundation, the U.S. Department of Agriculture, the Department of Defense and the Department of Energy, all supported by taxpayer dollars. Simpson is committed to reporting her research findings to the public and how it can benefit the public good.

"I have an obligation to tell them what I'm doing, and to be doing the work they feel is important," Simpson said. "Science is hard. It takes people who are very dedicated and committed and who inspire the next generation of scientists, to be sure we continue to focus on these huge, hard things and to reach out and engage as many people as possible. I value those things very deeply."

Interview with Angela Anandappa
By Diana Marcum

SAFER FOOD THROUGH RESEARCH, DATA ANALYSIS

Everyone has a relationship with food.

The Alliance for Advanced Sanitation's job is to improve sanitation methods through research and development, while working hand-in-hand with leading food companies.

Angela Anandappa is director of the Alliance for Advanced Sanitation, a public-private partnership between the University of Nebraska–Lincoln and food companies that invested in the Alliance for Advanced Sanitation. Its vision is to create a safer food supply through advanced sanitation approaches and practices.

Currently, 10 companies are a part of the Alliance: 3M; Cargill; Commercial Food Sanitation; ConAgra; Ecolab; Frontier Co-Op; Hershey's; Kellogg's; Neogen; and Nestle.

"This Alliance is about helping companies to work with the university, to access more research approaches dedicated to hygienic standards, methods and approaches. We'd like to be able to focus in on this part of manufacturing that is critical to food safety so that we can improve sanitation in a way that is meaningful to the industry," she said. Anandappa is a research assistant professor with the university's Department of Food Science and Technology.

"Sanitation is one of the core activities to make sure manufacturing plants, transportation and equipment are clean to protect you. It ensures you're not getting anything passed to someone who really does not need to be exposed to something bad for their health," Anandappa said. "A pathogen or some sort of environmental bug, or even a chemical. We don't want people to come into contact with anything that can be harmful to them."

Through the Alliance's research with food industry companies, the scientists are establishing an environment in which people can have a more secure relationship with food.

SANITATION FROM FIELD TO FACTORY

Sanitation in the food industry is the process companies go through to reduce or eliminate illness-causing pathogens, and ensure food is handled in a sanitary manner. Sanitation is a broad term used to describe managing the cleanliness of the food environment. Cleaning is an important part of the sanitation process. Once equipment is cleaned, sanitizers may be used as an added measure. For instance, if there were 10,000 bacterial cells, after the sanitation process the desired result would be zero bacterial cells.

"This is a numbers game, but the goal is to reduce the number of potentially present bacterial cells and make that a minimum," Anandappa explained.

An example of reducing harmful bacteria is the pasteurization process of dairy products. In the mid-1800s, Louis Pasteur, a French scientist, researched germ theory and prevention of disease through the elimination of germs. The process of pasteurization, or heating of dairy products, reduces bacteria that cause serious diseases. Milk pasteurization became mandatory in the United States in the 1930s.

Anandappa said that from the field to the factory, all of the equipment used or that the dairy products come into contact with – from silos to tubes, to mixers and more – needs to be cleaned and sanitized to meet the food industry's regulations.

"Any one of those pieces of equipment has to be cleaned at some point, with some frequency," Anandappa said. "And that is one of the things in the food industry which has to be done on a very regular basis."

Complex manufacturing systems are examples of where sanitation is needed most, she said. Like any equipment, materials can deteriorate or become damaged over time. Those damaged areas can collect food and bacteria that have the potential to grow. Anandappa explained that the challenge in sanitation is identifying those damaged areas before bacteria begin to grow, which is especially challenging in sophisticated, expensive equipment. Anandappa said solutions may be to better clean the equipment, work around the problem or replace the materials, but before any of this, sanitation workers must find and diagnose the problem.

USING DATA TO DIAGNOSE PROBLEMS

The Alliance for Advanced Sanitation exists to help the food industry devise more thorough and safer sanitation processes through research and data collection and analysis. Anandappa said the researchers begin with a company's sanitation processes and design improvements. Data on evidence of pathogens that is collected before, during and after the introduction of a new sanitation process provide a comprehensive understanding of the "before" and "after" processes, determining scientifically which process was better. The specific company evaluates the process to determine if it will work with the company's equipment, in the company's environment.

However, bacteria is only part of the great world of sanitation, Anandappa said. The Alliance intends to help companies in testing improved methods for reducing water and energy use, using fewer chemicals and developing more efficient ways to perform sanitation processes.

"It's important for them to know that this is something that they can use, so they're involved in designing the research project in the beginning, and that's what we're about," Anandappa said.

For more information, visit sanitationalliance.org

Interview with Curt Weller
By Lauren Stohlmann

NEBRASKA MANUFACTURING EXTENSION PARTNERSHIP

Centered at the university, ready to help manufacturers.

The vast majority of manufacturers in the United States have fewer than 500 employees – in fact, a great many have fewer than 50 employees. These small- and medium-sized manufacturers may have great business ideas, but little money for advice or training.

That reality sparked an idea for an outreach program throughout the United States, a program that would provide expert consulting, training workshops and customized assistance at reduced rates, to ease manufacturers' paths to success and strengthen manufacturing in the United States.

That was in 1988.

Now, there is such a program in every state that is part of the National Institute of Standards and Technology's Hollings Manufacturing Extension Partnership. It is named for Ernest "Fritz" Hollings, a senator from South Carolina from 1986-2004, who advocated for a national program that would provide resources to these manufacturing companies. The importance of this financial encouragement has renewed importance today, since there is a renewed emphasis on U.S. competitiveness in global manufacturing.

Curt Weller was director of the Nebraska Manufacturing Extension Partnership (NMEP) from 2013 to 2017, stepping down as NMEP director when he became head of the Department of Food Science and Technology and director of The Food Processing Center at the University of Nebraska–Lincoln.

The Nebraska Manufacturing Extension Partnership includes the university's Institute of Agriculture and Natural Resources, College of Engineering and Office of Research and Economic Development. The NMEP has a network of business advisers, technical experts and trainers in the university and with outside consultants. Its six-member staff occasionally works with other partners to provide services to Nebraska manufacturers, Weller said.

One of the goals of the Hollings MEP program is to strengthen manufacturing in each state and in the United States as a whole. Products such as machines, appliances, electronics, sensors, food and other manufactured items all can benefit the state's industries, including agriculture. The scope of manufacturing assistance includes water quality, quantity and usage; energy usage; minimizing waste streams; supply chain inconsistencies; and workforce training and development.

The National Institute of Standards and Technology (NIST) is the federal entity that helps provide funding to the manufacturing extension partnership, Weller said. Expert services are not free, but are charged at a competitive rate and include all kinds of manufacturing, from food to machines. Additionally, experts in NIST and the national network of MEP centers are resources to draw upon to answer manufacturers' questions or a sounding board to explore research opportunities. Twice-yearly meetings of directors of all the MEP centers provide opportunities to share information across the network, Weller said.

"It is a networking opportunity process, plus, it's an opportunity for the national MEP people to pass information to us," he added.

"The more we can manufacture here in the state, the better. If we can offer products at a fairly competitive price, well, I think Nebraskans would prefer to buy Nebraskan if at all possible," Weller said.

FOOD EXPERTISE

The land-grant mission of the university includes educating students, conducting research and extending those research findings to the people who can use the information, Weller said, whether through Nebraska Extension or through manufacturing extension, so the university is a natural host to the manufacturing extension partnership. The services of The Food Processing Center at the university are an example, since the vast majority of people understand food, Weller said.

"Maybe the goal would be to go to the market every day and purchase all fresh food, then come home and prepare it," he said. However, most people don't have the time to do that each day, nor do many people have daily access to fresh food markets.

"Instead, we have to depend on help – maybe some kind of a preservation method so that the food has some shelf life, or is already prepared, or takes minimal preparation. To do that, you need to understand the science on how to transform or preserve the food, including chemical, microbial and physical principles – and that is the realm of (food) engineers," Weller said, to provide new processes or tweaks to old processes to maintain the food's freshness and quality.

The Department of Food Science and Technology and its Food Processing Center are staffed by experts whose jobs include outreach to clients.

"The Food Processing Center in the Department of Food Science and Technology is primarily outreach, as are other programs associated with the department such as the Food Allergy Research and Resource Program (FARRP), the Alliance for Advanced Sanitation (AAS) and the Nebraska Food for Health Center," Weller said. The Food Processing Center provides consulting, education, technical and business development services; FARRP provides allergen testing to member companies; AAS develops improved sanitation practices for food processors; and the Nebraska Food for Health Center's research addresses critical human diseases and the agriculture and medical interventions that can improve health.

SUSTAINABILITY

The challenges are great, Weller said, including providing food sustainably for a growing world population.

"As humans on Earth, we still struggle every day to feed ourselves, and it is probably only going to get more intense," Weller said.

"There's more need. If you have more need, then you have to bring more resources to try and help meet that need, including water, and space to produce the various things you need," he said.

And then there's waste.

"Fifty percent of food in developing countries is wasted before it gets to the table," Weller said. The heavy losses in these other parts of the world result in food shortages, in part due to infrastructure, transportation or logistics. To Weller, these are issues that must be addressed and sustainability improvements to be made.

TRANSPARENCY, COLLABORATIONS

The Nebraska MEP assembles an annual report that provides an economic snapshot of the state's manufacturing industry, Weller said. This report shows the influence manufacturing has on the state's economy, offers information on current trends and suggests the future of the state's manufacturing, based on collected data.

"Since the federal government is providing some of the funding for this manufacturing extension partnership and the university is a public institution, all of the information is publicly available and is reported back to Congress," Weller said. "That gives our Congressional delegation some understanding of what's going on within their respective districts," he added. Additionally, the information is extended within the university and to the Nebraska Unicameral.

PLANTS

"The grand challenge that we are facing here is that we wanted to produce sufficient food, fuel and fiber for the global population that is projected to exceed 9.7 or 10 billion by the year 2050. Everything we do fits into that grand challenge."

Yufeng Ge

Interview with Richard Ferguson
By Bryce Doeschot

DRONES

Piloting a different way of seeing agriculture. Remote sensors improve efficiency for moisture, nutrients and pest control.

Flying over a field at 60 miles per hour is a device collecting data about the way a crop reflects light. The device sends the data to cloud-based software that gives a farmer real-time information about the crop. With that information, a farmer is able to make management decisions such as how much water or nitrogen to apply to the crop.

Born is a new age of managing fields of crops with unmanned aerial systems (UAS), often referred to as drones.

Viewing crops from the air is not a new practice for farmers, but new technology may make it easier to gather more data from crops.

"There are three platforms farmers can use to view their crops from above: satellite imagery, manned aircraft and unmanned aerial systems," according to Richard Ferguson, professor in the Department of Agronomy and Horticulture at the University of Nebraska–Lincoln.

"Although satellite imagery and manned aircraft have been in use for decades, drones are beginning to expand into the agriculture market," Ferguson said. Unmanned aerial systems have the ability to provide rapid, and even real-time data to the farmer.

"Unmanned aerial systems have the advantage of being relatively spontaneous. A farmer can get a view of his field within five minutes of arriving at his field, and you really can't do that with a manned aircraft or a satellite image," Ferguson said.

According to Ferguson, unmanned aerial systems can not only help farmers view their fields but also can help optimize profits while minimizing environmental impacts, specifically with nitrogen fertilizer runoff and water usage.

"I have a broad interest in how farmers use geospatial information for assessing how their cropping systems perform and using that information for improved management," Ferguson said. Geospatial information includes the location and geographic coordinates of a specific spot in a field.

IMPROVED EFFICIENCY FOR MOISTURE AND NUTRIENTS

According to Ferguson, managing irrigated agriculture fields with a UAS can make the system more efficient.

"The UAS may be useful in assessing irrigated systems weekly and recording the areas where the field needs more or less water," he said.

In addition to the water management, a similar flyover can detect areas in a crop field that need more nitrogen fertilizer. According to Ferguson, a farmer would then be able to apply water and nitrogen through the irrigation system on specific areas of the field. By gathering the data, a farmer would be able to take the guesswork out of irrigation and nutrient management.

One area of significant research is sensors, Ferguson said, by looking at crop reflectance characteristics and their reaction to a certain stress. The UAS is able to collect crop data by measuring reflectance that is generated from the crop.

"We're looking at crop reflectance characteristics and trying to relate what the crop looks like and how it reflects during certain stress," Ferguson said. To measure the crop reflectance, researchers must first measure how a crop reflects during normal circumstances – a reference for all other images or measurements. Once established, the UAS uses sensors to measure the light wavelength that is reflected from the crops.

"Sensors are continually evolving as are the technology and wavelengths that they can assess," Ferguson said. "It's a big area of research right now across our university."

Ferguson's area of research is nitrogen fertilizer and how different crops, hybrids and cultivars look to sensors in normal conditions.

"We will say 'for this field, for this crop, for this area, we know is not stressed for nitrogen and it looks this way.' And we will compare the rest of the field to that reference and say 'relative to that, it has some change and reflectance and certain wavelengths and then we can relate that to whether it needs nitrogen fertilizer," Ferguson explained. The same comparison might be made for other stresses, such as pests, he added, with comparisons made between the reference images and stressed images. Water stress, though, has unique reflectance in mid-infrared and thermal bands, leading scientists to quickly identify water as the stressor.

BIG CROP DATA

Right now, most sensors are image-based, Ferguson said. One kind of sensor is a "passive sensor" that uses the sun as a light source; then there are "active sensors" that have an internal light source. "Theoretically, we could collect information about every square meter, every second," Ferguson said. But that would accrue millions of data points in a field every day, and that becomes a great deal of data very quickly – more than could be processed on a spreadsheet. Most unmanned aerial systems have onboard data storage for their sensors, but Ferguson said increasingly, that data may be linked to cloud-based systems.

A cellular modem or a satellite connection that loads data into a cloud-based server is needed so a farmer or a scientist can access the information anytime, anywhere, from any platform, Ferguson said. That is not commonly done with agriculturally oriented unmanned aerial systems, but Ferguson said he believes wireless transmission of data is in the future, going from the unmanned system to the ground, to a server for instant data processing.

LEGAL RESTRICTIONS

Ferguson said that using a UAS to observe crops requires Federal Aviation Administration (FAA) permits and certifications if the result of observing the crops leads to an economic benefit.

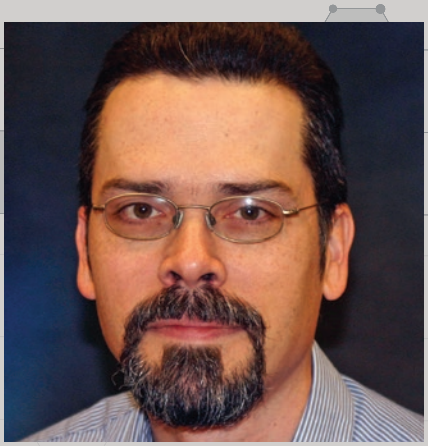
"If you want to manage your crop, that becomes a commercial enterprise, so you can't just buy a UAS off the shelf and go out and fly it. To fly commercially, you need to have a remote operator's license certification from the FAA, which requires passing a knowledge exam," Ferguson said.

Beyond passing the exam, Ferguson said that the FAA has rules on the way a drone is flown.

"There are restrictions in terms of height; you can't be over 400 feet above the ground. The UAS has to be within your line of sight while flying and you can only operate one at a time," Ferguson said.

Because of the legal restrictions, Ferguson expects that some farmers will prefer to hire a company or person that has the certification to provide drone services. Additionally, Ferguson encourages farmers to try the technology out to see if it is a right fit for their operation.

"I encourage farmers and their advisers to not hesitate to try it out. It's easy to do and can be an economic benefit for a farmer's operation. Just be sure that you do it within regulatory considerations."



Interview with Jeff Bradshaw
By Aliesha Dethlefs

BIG DATA AND WHEAT STEM SAWFLY

Computing data shows quantity, location of pests.

The broad impact of Jeff Bradshaw's research is to improve the lives of agricultural producers in western Nebraska, improving the human condition along the way.

Bradshaw is an associate professor of entomology and Extension entomologist at the University of Nebraska–Lincoln Panhandle Research and Extension Center in Scottsbluff, where he conducts research on the wheat stem sawfly.

Nebraska is in the top 12 wheat-producing states in the United States, harvesting nearly 70 million bushels annually.

THE WHEAT STEM SAWFLY

The wheat stem sawfly is a small black and yellow wasp that attacks wheat. As an adult, it lays eggs in the wheat stem. Once the eggs hatch, the larvae feed on the inside of the wheat stem, causing physiological problems with the plant and loss of yield.

Bradshaw said as the season progresses, the insect migrates down the stem, girdles the stem and pupates inside the crown. The girdling causes the wheat tiller to break if there is a windstorm, which results in lodging that impacts the wheat yield. The lodging of the wheat stem sawfly also can cause residue loss in dryland wheat systems.

Bradshaw said the wheat stem sawfly primarily is a pest of the western United States, including Nebraska. Winter and spring wheat growing regions overlap with the range of the wheat stem sawfly. The pest typically affected the northern Great Plains prior to 2010, but since that time, the wheat stem sawfly has moved farther down into the central and southern plains, including Nebraska. The wheat stem sawfly currently impacts Colorado, Kansas and Nebraska – states that now are on the most eastern and southern edge of the sawfly's range.

Wheat is the primary crop impacted by the wheat stem sawfly, but the pest can wreak havoc on the entire dryland system, Bradshaw said. The dryland system's nonirrigated agriculture is used to grow field crops in regions with a cool, wet season and a hot, dry season that typically receives less than 15 inches of annual precipitation, he said. The wheat stem sawfly can infest fields to the point that there is little residue left in wheat fields; without residue, the fields can't catch snow over the winter, eliminating a source of needed moisture. The reduction in soil moisture impacts any crop that is in rotation with wheat, thus impacting the overall dryland ecosystem.

The Nebraska Panhandle is in the eco-region classified as semiarid high plains; primarily grassland. Much of the area is above 3,000 feet in elevation, Bradshaw said. Historically, pioneering Nebraskans built houses made of sod instead of wood because there was an abundance of grassland, but few trees – due to the semiarid environment.

"Once you understand the dryland system, you can understand the potential impact of the wheat stem sawfly," Bradshaw said.

"Elevation and annual precipitation both have a profound impact on the crops that can be grown. Generally, high elevation and low precipitation lower yield potential. Our average annual precipitation is very near the minimum soil-moisture requirements to grow common commodities, like corn or wheat, profitably," Bradshaw said.

Bradshaw conducts research on the wheat stem sawfly in a partnership with producers, agronomists and co-op agriculturalists, he said. He sends out a survey on the wheat stem sawfly that includes sampling protocols and procedures on how to sample fields for the wheat stem sawfly. In some cases, producers collect samples for the researchers to help identify fields and gather more diverse data. Bradshaw sought out collaborators and cooperators in the wheat stem sawfly project; they formed a network of agriculturalists, growers and co-op partnerships that collect data that report findings to growers.

"We can improve the viability of wheat by finding some sort of resistance trait that is made to be targeted regionally, because we have this survey data set and we can help improve the life out here of some of these growers," Bradshaw said.

DATA AIDS SAWFLY RESEARCHERS

"Big data" is a common term in the scientific community for large, complex data sets in which a researcher can look at trends or certain attributes of the data that could be described in a way that couldn't happen with a smaller data set, Bradshaw said.

The role of data in wheat stem sawfly research involves understanding and describing the sawfly population and its progression, Bradshaw said. The information can be shared with collaborating producers, the Nebraska Wheat Board and with the United States Department of Agriculture, among others. Sharing the research data with organizations confirms there is a problem and establishes the extent of the infestation. Nebraska Extension works to share the collected information with the state's wheat producers.

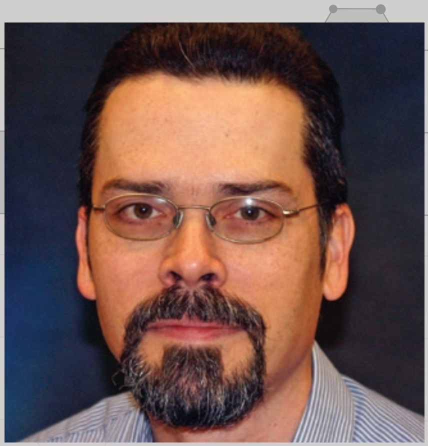
The wheat stem sawfly survey results are available to the public and other research is published in peer review journals. Field data also is collected, which provides data associated with the samples. Samples could include when, where and how the data was collected, from what crop and from what landscape. Bradshaw hopes to conduct more research and analysis in the future in regards to what factors are impacting the wheat stem sawfly population or the parasitoid population. For more information on the data collected, visit cropwatch.unl.edu/2016/wheat-insects-2016.

The survey helped make producers aware of the sawfly problem and improved the ability of producers to identify the pest. The producers also report their own ideas to Bradshaw.

"A big part of the project is just providing the information back to cooperators, giving them a platform to think creatively about how to solve some of these problems," Bradshaw said.

RESEARCH AND EXTENSION CENTERS

The Panhandle Research and Extension Center in Scottsbluff is one of the university research and extension centers located in key sites throughout Nebraska, in both rural and urban areas. They are operated through the Institute of Agriculture and Natural Resources, in cooperation with the Agricultural Research Division and Nebraska Extension. The purpose of each center is to conduct research and extension programming that is relevant to the region, serving the economic, environmental and social needs and interests of that center's region, as well as all of Nebraska.



Jeffrey Bradshaw
Associate Professor of Entomology and Extension Entomologist
Panhandle Research and Extension Center

SERVING NEBRASKANS THROUGH RESEARCH AND EXTENSION

MY WORK IS IMPORTANT BECAUSE IT'S NEEDED.

The first way it's important is my location. I base here, at the Panhandle Research and Extension Center in Scottsbluff, because of a longstanding philosophical belief in Extension that we need to be where the people are. We have held that belief since the Smith-Lever Act of 1914 established Cooperative Extension. That has been the spirit of the experiment college for our land-grant university.

Second, because I am here, I know my environment, I understand my clientele and their needs, so I can be responsive.

Third, the importance of my position being located here is so I can have some foresight. I can look at the cropping systems we have today and look down the road for the next cropping system that is going to make the farmer's operation more sustainable. I want to make sure I am here to look out for the pests that are causing a challenge; for beneficial insects that might bring some benefit.

To me, that is the importance of this position. There is a lot to know, so being here, and having someone to take on that complexity of life, is important.

"America's jazz is to music as Extension is to science communication."

-Jeff Bradshaw

Interview with Yufeng Ge and James Schnable
By Breanna Jakubowski

SCIENTISTS' COLLABORATION

Developing technologies that can eventually 'alter the way we live.'

If you've ever driven through Nebraska in a dry year, you've seen the leaves of corn rolling up from too little moisture.

But how much water does corn actually need at each stage of growth, and can cultivars be developed that can thrive with less?

Researchers at the University of Nebraska–Lincoln are learning more about the growth rate and the percentage of water in the plant through phenotyping and through research facilities that carefully monitor growth, water and environment, recording it all with specialized photography and sensors.

Plant phenotyping research may make it possible to develop locally adapted crop varieties that produce higher yields. That could be especially important in geographic areas where weather or other conditions traditionally produce lower yields.

Scientists Yufeng Ge and James Schnable collaborate on research that measures and compares physical traits of corn, using a high-throughput phenotyping system in the Greenhouse Innovation Center at Nebraska Innovation Campus. On the surface, the collaboration seems ordinary, but it is complex – on several levels.

Ge is an assistant professor in the university's Department of Biological Systems Engineering; Schnable is an assistant professor in the Department of Agronomy and Horticulture. Ge, the engineer, works with technologies such as instrumentation, cameras and collection of informative images, while Schnable, the agronomist, works with the plant traits and genetics. Together, they are making progress toward higher, more consistent crop yields.

"These are the first steps in accelerating development of technologies that can alter the way we live," Schnable said. The work right now is making first advances so phenotyping equipment becomes less expensive and easier to integrate into every farm in America.

Technological advances have increased speed and precision in terms of fertilizer applications on the farm and selecting plants for genetic potential, but until recently, the actual measurement of the plants slowed the plant breeding process. Now, high-throughput phenotyping offers the potential to make everything go faster, Schnable added.

The high-throughput phenotyping system is one of only a few in the United States. It uses sensors, robotics and computer technology, Ge said, rapidly measuring and comparing the physical traits of individual plants and capturing it all in high-content images.

The scientists conduct research on the university's test fields, located both right on campus and around Nebraska, but also in the Greenhouse Innovation Center. Climate can be controlled in each of the greenhouse's two sections, so a scientist can conduct research on plants' growth in a specific temperature or relative humidity. The greenhouse has 672 plant pots; each can hold one plant. There are three automated watering stations that measure how much water each plant used since it was last watered and can add individually specified amounts of water to each plant each day during a research experiment.

The greenhouse phenotyping facility has the capacity to capture tens of thousands of images a day in different forms, Ge said, with five kinds of sophisticated cameras: a consumer-grade camera with higher resolution; a fluorescent camera that measures the chlorophyll in the plant; a thermal infrared camera that measures the temperature of plant leaves and stems; a near-infrared camera that looks at plants' water content; and a hyperspectral camera that captures the reflective spectrum of a plant leaf. The hyperspectral camera also quantifies differences in the chemical composition of plants, including variation in water, pigment and cell wall composition.

The system stores all of those images in the computer and database.

'SEA OF DATA'

Thousands of photos are taken every day, representing an immense amount of data that is analyzed for conclusions about plant growth and water consumption.

"It is the responsibility of the researcher to go into that big sea of data, trying to figure out what you are looking for," Ge said.

Ge and Schnable collaborate with computer scientists and statisticians, who work with the data after the cameras capture the images. Even a simple experiment, Schnable said, can generate hundreds of gigabytes of data, with the possibility of growing to terabytes. The team of researchers is working on challenges of data transmission so others can easily access the data. Another challenge, Schnable said, is capturing the metadata, such as the corn plant's variety, genotype, growth environment and treatment.

After the image collection, they face the challenge of turning the pictures into numbers, which statisticians need to work with the data.

"After the engineering, we have lots of images of individual plants or plots, taken many times throughout the growing season," Schnable said. These images are added to the data collected with non-high-throughput phenotyping, such as bushels per acre in yield; height; flowering; climb and more, which all are numerical values.

"How you take an image with a cellphone camera or something more complex, like the hyperspectral photos, and reduce them to numerical values that are informative about the health or stress tolerance or yield potential of a corn, soybean or sorghum plant – that's one of the real analysis challenges," Schnable said.

INTERDISCIPLINARY COLLABORATION

The collaboration between the two scientists is rewarding, Ge said. It also is the research trend, driven by funding agencies that suggest a variety of perspectives when solving a challenge.

"I trained as an engineer and I always interacted with engineers, and we would talk about things like tractors and irrigation pivots and precision agriculture, remote sensing and instrumentation. But it wasn't until I joined th university and started working on the high-throughput phenotyping research that I realized it opened up a whole new arena," he said.

Schnable said that on a fundamental level, it means that "I bring the plants and he brings the sensors and computers" to the collaboration.

"I have an experiment where I'm growing plants in Mead (at the university's Agricultural Research and Development Center). I can go to Yufeng and he already has developed this wonderful sensor platform that he can roll through the field," Schnable said. "I can say, 'well, if you're developing this anyway, can you image these plants for me?'"

The university invests not only in the high-throughput phenotyping greenhouse at Nebraska Innovation Campus, but also in the phenotyping field facility at the ARDC in Mead, Ge said.

"Everyone understands just how vital this work is, and that is very powerful – both in terms of the resources the state invests in it, but also in the mindset of students you meet, the people you work with on campus. They understand just how important agriculture is," Schnable said.

TIMELY RESEARCH

Ge said the research team wants to find out whether hyperspectral imaging can non-invasively measure biochemical traits in the plant leaf, such as nitrogen, phosphorus and potassium. If it can be done, he said, farmers will benefit by having to apply only the amount of nutrients the plant needs, and no more.

Schnable said that in the next decade, there will be more pressure to apply only the specific amount of nitrogen or other fertilizers that are needed. If research can quantify plants' requirements more precisely, farmers can adopt the techniques that will save them money, he added.

"The grand challenge that we are facing here is that we wanted to produce sufficient food, fuel and fiber for the global population that is projected to exceed 9.7 or 10 billion by the year 2050. Everything we do fits into that grand challenge," Ge said. Using the phenotyping method, scientists are able to look at not only Nebraska, but around the United States and potentially to developing countries like Africa, India or China.

"That is the key to phenotyping; you want to develop crop cultivars that can survive in different environments," Ge said.

Interview with David Hyten
By Breanna Jakubowski

IMPROVING SOYBEANS FOR FARMERS, THE WORLD

Finding one's ancestry through 21st-century DNA analysis is increasing in popularity. Similar technology is being used at the University of Nebraska–Lincoln to improve soybeans so they can help feed a quickly growing world population.

Instead of breeding new varieties randomly, scientists are using molecular technology to help select genes that are scientifically proven to increase soybean productivity, resulting in soybean varieties that yield better than varieties developed in the past.

David Hyten is the Haskins Professor of Plant Genetics and associate professor of soybean genetics and genomics in the Department of Agronomy and Horticulture. He specializes in improving soybeans through the use of molecular technology for better yields and for resistance to disease, insects and drought. Hyten and other scientific collaborators work with soybean varieties, experimental lines and wild soybean relatives to determine which genes are responsible for specific traits, selecting genes that will create robust varieties.

ESSENTIAL WORK, CRITICAL TIME

"This work is important because it's helping to increase yields," Hyten said. By 2050, the world population is expected to reach 9.8 billion, a growth of more than 2 billion from the current population.

"While we may enjoy food surpluses now, by 2050 we're going to have a food deficit. If we continue on our current rate of gain for our crops, we're not going to be able to feed those 9.8 billion people. By using a combination of our genomics research, better agronomic practices, bringing in new traits through transgenic technology, and gene editing current genes to improve their function – the goal, and really, the need is to increase our yield gains so we can meet that demand," Hyten said.

Hyten's research is improving soybeans for farmers at a faster rate than would be possible by breeding new varieties at random.

"We can 'stack the deck' by knowing the underlying genes and selecting the best genes from both parents. Using molecular techniques, we can get an improved soybean variety quicker," he said.

The molecular techniques Hyten uses are applicable to all crops, to animals and to humans. Similar to the commercial DNA analysis to determine a person's ancestry, ethnicity and disease susceptibility, Hyten can discern similar information about crops.

"We can tell how related one variety is to another variety, what type of disease resistance the variety confers and if it has beneficial genes for yield that we might want to integrate into our current elite varieties," he said.

One of the main technologies Hyten uses is next-generation sequencing, taking the DNA from different soybean varieties and sequencing it. Hyten refers to next-generation sequencing as "revolutionary" in plant genetics, advancing the science at a critical time in the world. "Probably the biggest breakthrough in crop genomic research has been next-generation sequencing. It is now possible to obtain DNA sequence from 1,000 or 10,000 varieties. The sequence shows variations in different crops that we cannot see visually. We're able to decode the DNA in the different varieties and compare it to see which differences are important to agronomically important traits," he added.

The leading-edge study of molecular biology also requires a team of scientists to analyze and apply the massive amounts of data to crop improvement. There has to be a collaborative work environment with statisticians, bioinformatics specialists, computer scientists, plant breeders, plant pathologists and plant physiologists. Additionally, there is a need for large storage capability, due to the massive amounts of data generated by sequencing thousands of genes.

ADDRESSING CHALLENGES

The environment crops grow in is highly variable and they face a number of significant challenges, including heat stress, droughts, floods, cold stress and other environmental stresses, he said. This creates a challenge for growing food on a consistent basis for an increasing world population.

"We're always trying to breed for better crops that can produce good yield in any environment they might encounter in a field," Hyten said. Discovering genes that help with this yield stability across environments is another area of emphasis for Hyten's research program.

"It is important to ensure that farmers in different areas with differing rain patterns, both return high yields," he said. This yield stability also will help in drought years. Crops with better genetics will have a higher probability of producing a sufficient yield to feed people and animals.

"We're trying to learn more about traits that make a soybean variety more resistant to heat stress and drought stress as part of our yield stability research," he added.

Hyten collaborates with soybean breeders and other scientists to perform greenhouse and research field testing throughout the United States to learn more about the genetics of drought stress.

"In the greenhouse, we can control the amount of water a plant receives to learn about how the genes of drought-tolerant soybeans respond to drought stress, but the results may not always translate well to a farmer's field. In our field research, it may be more difficult to control the exact amount of water the plants receive, but we can simulate drought stress by using plastic covering to limit plants' access to water. The field study simulates drought stress in a situation that is closer to what would happen in a farmer's field," he said.

Nebraska's soybean genomics research program has international application through potential collaborations with scientists in Brazil, Argentina, China and Canada, as well as throughout soybean-growing areas of the United States. Through these collaborations, "we can make more progress working together than we could alone, so it's the synergy of teamwork," he said.

New technology will continue to change how crops are improved. Currently, tools are available so scientists can edit genes directly. Understanding which genes contribute to disease resistance, better yields and drought stress will help scientists to implement these tools to continue improvement of these important traits for the challenging environments they will encounter.

Funding for Hyten's research comes from the Nebraska Soybean Board, the North Central Soybean Research Program, and the United Soybean Board.

Interview with Joe Luck
By Cassandra Huck

PRECISION AGRICULTURE

Engineering solutions for the 21st century.

Meeting the food and fiber needs of a growing world population requires changes in traditional production techniques and attention to efficiency and sustainability. Precision agriculture is a leader in this transformation, and Joe Luck is a leader in precision agriculture.

Luck is an associate professor of biological systems engineering and Extension precision agriculture specialist at the University of Nebraska–Lincoln. Precision agriculture is a combination of hardware and software tools that provides information to make farming more sustainable and efficient, Luck said. The hardware components include technology, such as sensors, that collect field data, while software components include analytical tools and data generated by the systems. Together, they allow agricultural producers to apply less water and fewer chemicals, protecting water and other natural resources and saving producers significant input costs.

"Precision agriculture is going to be the way of the future. In the future, farms are going to be larger. We can help manage those fields, with sensors automating parts of the crop management system," Luck said. Even now, producers use sensors to collect data on ag fields, resulting in maps indicating the variable needs for water and fertilizer in each area.

RESEARCH RESULTS

Project SENSE, a three-year research project conducted from 2014-2017 through the Nebraska On-Farm Research Network, was a collaboration between 20 Nebraska agricultural producers, Nebraska Extension, the Nebraska Corn Board, the U.S. Department of Agriculture and five Natural Resources Districts. The acronym SENSE stands for Sensors for Efficient Nitrogen Use and Stewardship of the Environment. The research project used sensors to determine how much nitrogen fertilizer a crop needed – even based on differences within fields. Research results from 2016, the second year of the project, indicated that crop canopy sensors saved 34 pounds of nitrogen per acre and saved $7 per acre over grower management.

DATA COLLECTION, ANALYSIS, SECURITY

Today's farms are being passed down to future generations with electronic records of yield history and application history, Luck said, which are valuable to farms' new owners.

That data, and the technology used to collect, analyze and securely store it, represents changes in thinking and in the computing tools farmers now use.

"Big data, in my opinion, refers to data that we can't manage on a desktop computer," Luck said. "There has to be some type of cloud computing element to it."

Many forms of agricultural data are just too large for a desktop computer and farmers and specialists must rely on cloud computing and processing, which refers to large, offsite computer servers. Some of the tools farmers are currently using in the fields automatically send data into a cloud processing system for storage and analysis, Luck said. The cloud processor returns data analyses and maps to the farmer.

"A lot of networks and platforms are pulling data sets from all across the country and even from other parts of the world, and performing some sort of data analysis," he explained. The data analyses assist with irrigation management decisions and with nitrogen application decisions, which can affect producers' pocketbooks.

But the data may also be available to others.

"People are concerned about the data once it leaves their computers. Once it hits the web, it's like everything else – it's been backed up on servers in different places," Luck said. "Another element is what people will do with others' data once they have it. Can they leverage it? This business of data agreements has become a huge issue in agriculture."

To address these concerns, the university became a founding member of the national Agricultural Data Coalition, which Luck calls a "real benefit to the industry." The goal of the coalition is a national online repository where farmers can securely store and control the information collected by their equipment and operations. Before any data is shared with third-party interests, the information is scrubbed and formatted for uniform transmission. It gives the farmer complete control of the data, which doesn't leave, or get networked with anyone or anything until the farmer gives permission.

"I think people need a cloud storage solution for their data just because you need that kind of double backup element," Luck advised. "Always store raw data and keep an additional backup of that on your hard drive or in a secondary location."

Luck and other Extension specialists conduct workshops for producers and other ag-related professionals, teaching them to work with agricultural data so they get the best possible understanding from the collected data and the analysis of that data.

"If you don't have that basic understanding of data and science, the information could lead you in the wrong direction," he said. "We've had some good comments from the workshops, so hopefully we're being helpful to people who are trying to understand how to use the technology and the data."

EXTENSION: EDUCATION, BENEFITS

Nebraska Extension is a part of the university and provides research-based knowledge through teaching, experiential learning opportunities and publications to Nebraskans. Extension specialists, like Luck, are located on the university's East Campus and at three research and extension centers across the state.

Luck's Extension work helps producers across Nebraska who want to learn new techniques that make farming more efficient and save them money.

"The Extension element is probably one of the most fun parts of the job," Luck said. "I always consider when we're out working with producers in their fields an Extension opportunity, and it's a great way to get out and see the state and meet different people," Luck said.

Luck focuses on site-specific management strategies, precision agriculture technology use and farm management software training in winter workshops in locations throughout Nebraska. During these workshops, Luck and his team of researchers set up computers and take producers through the steps of quantifying yield versus terrain, writing prescription maps for on-farm research studies, and how to determine field profitability using precision agriculture techniques.

FEEDING THE WORLD

One of the main issues with providing enough food for a growing world population is the transport and logistics of food to people who can't grow it where they are, as well as the significant issue of climate change and climate variability, Luck said.

"I think if we can get everyone to produce with higher efficiency – and I think some of our producers here in Nebraska are – we would be a lot further along than we are right now," he said.

Interview with Suat Irmak
By Victoria Talcott

MONITORING EVERY DROP

Technology, coupled with education, helps to conserve irrigation water.

As an 8-year-old on his family's very small, rented farm in Turkey, Suat Irmak knew farming should be better, easier and more efficient. He decided then to chart his life's course toward making that a reality.

Irmak is Harold W. Eberhard Distinguished Professor in the Department of Biological Systems Engineering at the university, where he also is Extension soil-water and irrigation engineer. Irmak conducts research and Extension programs throughout Nebraska, trying to make farming better, easier and more efficient.

"We try to couple engineering and scientific principles with practices to help address real-world issues related to agricultural productivity, water resources, irrigation, crop water use – and teaching our growers, crop consultants and state agency partners to make better decisions in their practices," Irmak said.

RESEARCH PROJECTS

Irmak and his team have numerous large-scale research programs, all of which have applications for farmers, crop consultants and governmental agencies, he said.

Evapotranspiration

Evapotranspiration is the combination of evaporation from the soil surface and transpiration from the crop surface, Irmak explained.

"We deploy 11 advanced flux towers to measure surface energy fluxes continuously from 12 or 13 different vegetation surfaces around the state," he said. The data sets help the scientists understand crop response to different environmental variables, water, climate and soil conditions. Out of that information come better management strategies for different cropping systems, which inform the people who can benefit from the data and information, he said. Essentially, the goal is to convert scientific research and data into information and strategies that can be implemented in practical applications to enhance crop water productivity (crop water use efficiency).

Climate change

Climate variables greatly impact agriculture and water resources, he said. Irmak's research program on change in climate variables studies how climate variables have been changing, and by how much, and what the potential implications are to agricultural productivity, water resource assessment, planning, and for future projections.

"We do this for every county in Nebraska, but we have expanded that work to the entire Great Plains – from the panhandle of Texas all the way to the Dakotas and then from western Iowa to Colorado," Irmak said. "We have looked at more than 800 counties individually – the study area covers about 30 percent of the surface area of the continental United States – so we have some understanding of how climatic variables are changing and what they mean in terms of impact on agricultural and water resources, which can be used to develop adoption strategies for changing climatic conditions to enhance agricultural production efficiency," he added.

Variable-rate irrigation and fertigation

Variable-rate irrigation and fertigation comprises yet another large research project, Irmak said.

Variable-rate irrigation is a practice in which a producer can change the water and/or nutrient application rate based on the demand by the crop and the soil in the field. Some parts of a field may need different amounts of water, so research is exploring technology that will allow center pivot irrigation systems to apply just-right amounts of water to specific parts of the field.

Variable-rate fertigation is the application of the correct amount of fertilizer to each part of a field through an irrigation system.

There are challenges with both, Irmak said: identifying the specific needs of each part of a field; quantifying the needs based on space availability; having farmers purchase a machine that has variable-rate capability; and programming the center pivot unit to accurately deliver just the right amount of water, or water and fertilizer, to each part of the field.

Collecting real-time data from the field and using this data set for real-time decision-making and changing the water and/or fertilizer application rate is a challenging task.

"While we made substantial progress on this challenging task, I think we still have a long way to go in terms of making that process accurate and robust," he said. Natural variabilities include land slope, physical and chemical characteristics of soil and water uptake, variability in crop emergence and growth and development, etc. Determination of the economic feasibility of variable-rate water and nutrient applications for different spatially-variable fields is another challenge.

"Information and data about variable-rate irrigation and fertigation technologies continue to be developed through research and provided to the users," Irmak said. "The level of spatial variability in a given production field that justifies the use of variable-rate technology is still not well-understood. However, this is a critical point for analyzing the economics of the technology in terms of net farm return – and we are working on these important topics," he explained.

TECHNOLOGY AND DATA

Irmak and his research team conduct outreach work with more than 1,400 growers in 76 counties in Nebraska, as well as with Natural Resources Districts (NRD) and with Nebraska Extension, implementing technologies and helping growers to incorporate new technologies and make good management decisions.

"It has been one of the most effective programs that truly couples research and Extension to have large-scale, positive impacts with an excellent team effort," Irmak added.

Growers have either automated or handheld sensors that measure soil moisture in their fields. They use the data that are measured directly from their production fields for their management decisions, Irmak said.

"We have a website where our collaborators in that Extension network upload their weekly crop water use. If there are neighbors in their area who are not part of our network, they can still go online and use that information to make good decisions in their fields," he explained.

In another research project, flux towers continuously measure evapotranspiration and more than 20 variables for irrigated and rainfed grasslands, alfalfa, switchgrass, corn, soybean, sorghum, popcorn, black turtle beans, watermelons, vineyards, cover crop-corn rotation and other cropping systems under different irrigation methods, such as subsurface drip, center pivot, and gravity irrigation and tillage practices, such as ridge-, disk, and no-till, he said. The towers have been operating every hour, nonstop, for more than 12 years.

"We have remote access to them from our laptops, and we connect to the systems and download the data," he added. That remote access also indicates whether the flux towers are operating correctly, or if someone must travel to make repairs to ensure good quality data collection.

One of the challenges in conducting research with new technologies is that adjustments or repairs must be made in person. Often, Irmak or a member of his research team must travel hundreds of miles to manage the technology, including in winter, since these towers operate year-round and measure nongrowing (dormant) season evaporative losses for better water balance analyses, he explained.

NEBRASKA'S IMPACT

If the current growth projections hold, by 2050, the world population is expected to grow to more than 9 billion. Irmak believes that Nebraska's farmers can substantially contribute towards meeting the increasing demand for food, fiber and fuel through research and adoption of best practices to produce those products.

"It is an extremely difficult task, but I have confidence that with good scientific and research programs, coupled with robust Extension/outreach programs, we can achieve that," he said.

Irmak also has confidence that growers have enough trust in science and research to adopt new technologies that can save water and money while maintaining or increasing crop yields. People may resist change initially, but once they trust the researchers and understand the information comes from good-quality, objective research, they will adopt new techniques, he said.

"During this process, it is also crucial that we genuinely care about growers' issues and do our best to develop good-quality research programs and disseminate the information and data through effective platforms to help our growers to resolve those real-world production issues," Irmak added.

"Research and science are always coming to rescue us. Scientific discoveries can change human civilizations' fate," Irmak said.

IRMAK'S TEAM

"The goal has always been to make sure we establish good-quality research projects that address real-world issues so we can make contributions to the environment, to people or both," Irmak said. Good-quality research is characterized by proper research setup, data collection, data analysis and accurate interpretation and conclusions based on the analysis and right interpretation.

"The results and conclusions we have from those projects will impact somebody, and we have to make sure we are doing our best to carry out quality research that will result in the best conclusions to deliver the best information that will enhance decision-making in practice," he said.

His team always strives for that, he said.

One of his main goals is to educate, train and mentor the next generation of scientists, researchers, educators and managers. Irmak's research team has consisted of a large number of students over many years.

"I established my research projects and involved my graduate students in almost every step, in an effective team environment, so they can see how the process works, the mistakes we make and how we solve them, and learn not to repeat them, so they can do things better than I do when they become faculty members, researchers, scientists or educators. And, we need more of that," he said, to address the complex issues facing the world.

Another goal is to establish globally recognized programs in research, Extension and education so the University of Nebraska's research programs are recognized for quality in regional, national and international platforms and used as examples of signature programs by other states and countries.

"The ultimate goal is to be seen as one of the leaders in the field and where other people can replicate what we do to address real-world issues and help people to manage their systems better and enhance production efficiency," he said.

Interview with Daniel Schachtman
By Emily Long

CONNECTING NEBRASKA'S ROOTS

Data analyzed for ideal microbes that help plants grow in stressful environments.

Plants require strong roots and good soil to thrive and produce a bountiful crop, but that is a challenge when soil is affected by drought, low nutrients or salinity.

Daniel Schachtman, a University of Nebraska–Lincoln professor of agronomy and horticulture, studies how root systems and soils affect plant growth, disease resistance and crop yields and ultimately, how crops can grow in poor soils and drought conditions.

UNDERSTANDING MICROBES, IMPROVING GROWING POTENTIAL

Schachtman's research is conducted in hopes of finding an ideal group of microbes that will help plants grow in stressful environments. His focus is in understanding the microbes – bacteria or fungus – that interact inside and outside of the plant root. He is learning how the environment affects the community of root microbes, called the root microbiome, and how that community impacts the plants. Schachtman and scientists with whom he collaborates collect data on roots' environmental stresses, including low nitrogen, salinity, drought and water deficit. Some of his research studies root exudates, which are compounds the root releases into the soil on which microbes feed and grow. Exudates include hormones, amino acid, organic acids and sugars that are released by plant roots and act as a source of nutrients for the microbes, Schachtman said. He hopes eventually to engineer the plants so they can grow in low-water, low-nitrogen conditions or in soils that are experiencing drought, with the assistance of specialized microbes.

If Schachtman and his collaborators are successful, it is possible that farmers could use less fertilizer in their fields, reducing their costs, keeping yields high and reducing groundwater pollution, he said. For example, the nitrogen from plants in sandier soils in Nebraska leaches into the water table, eventually making its way downstream and polluting waterways. Schachtman's research currently is in the process of finding microbes that would help plants make their own nitrogen to solve this problem.

"Microbes are cool. They can be applied to agriculture but there are all sorts of industrial uses for microbes also," Schachtman said. Microbes are useful in many different ways, from making yogurt to making ethanol, he added.

Another large research project involves the university's Center for Root and Rhizobiome Innovation that engages researchers from the University of Nebraska–Lincoln, the University of Nebraska at Kearney, Doane University and the University of Nebraska Medical Center. Schachtman said researchers are screening 400 lines of maize and will conduct detailed studies on 30 lines that have very different exudate profiles. They will be planted, then scientists will measure how the microbial communities change across the different lines depending on exudates. The Center for Root and Rhizobiome Innovation was established and funded by the National Science Foundation Experimental Program to Stimulate Competitive Research (EPSCoR) program. His work as part of this project focuses on maize and on differences in exudates, but the research will transfer to other crops.

Schachtman said yet another research project focuses on sorghum and growing high biomass yielding plants on marginal land for making cellulosic ethanol – this marginal land might be low in nitrogen or might not get enough water.

"We are using sorghum as the plant we are studying, and we are screening lines for drought tolerance and nitrogen deficiency," Schachtman said. "We hope to find an ideal group of microbes that will aid plants that are growing in these low-nitrogen, low-water or droughted soils."

Schachtman started his research in 2014, when he joined the university faculty, by sampling fields and water in many Nebraska locations, looking at how nitrogen and drought alter microbial communities. Through the research processes, large amounts of data are collected about the microbes.

"These data sets are huge," Schachtman said. "There are special open-access programs available for handling all of the (DNA) sequencing data, checking the quality and getting it into a form we can analyze, and some programs that allow us to do a basic analysis," he explained. However, it takes specific expertise to analyze large amounts of complex data – a combination of knowledge of both biology and statistics, called bioinformatics. Schachtman's laboratory includes post-doctoral researchers, graduate students and technicians who are involved in analyzing and making sense of the data using a graphical representation of the data and statistical methods to test for differences in treatments and in genotypes – always in the microbial communities.

Through this data collection, Schachtman is able to learn what microbes have the potential to provide high yields, nitrogen and drought resistance. The vision for this research is to lower costs, increase profit potential for farmers and protect our natural resources.

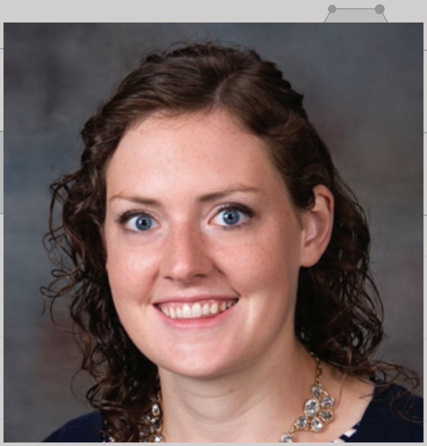
CENTER FOR BIOTECHNOLOGY

Schachtman also is director of the university's Center for Biotechnology. Founded in 1987, the center provides faculty, staff and students with access to state-of-the-art instrumentation and experts in multiple areas of research. The center has grown to include five core facilities: bioinformatics; flow cytometry; microscopy; plant transformation; and proteomics and metabolomics, each led by an expert in that discipline. Each core facility houses scientific instruments that can each cost up to a million dollars; the core facilities eliminate the need for multiple laboratories to purchase their own equipment by offering fee-based services and training to faculty, students and staff.

"Plant scientists bring in plants; people studying animals bring in tissue culture samples; people interested in microbes will bring in bacterial or fungal samples; engineers bring in fabricated materials, biological engineers will bring in tissue samples," he said. As an example, one company is interested in assuring the purity of its vaccines, so the Center for Biotechnology experts examine the vaccines for viral particles to be sure they are clean, he explained.

The Center for Biotechnology scientists also conduct periodic training sessions and a course for students in which they learn about each core facility.

"Our goal is to serve our customers, process the samples quickly and provide the instrumentation so faculty have the tools they need for their research," he said.



Interview with Laura Thompson
By Diana Marcum

NEBRASKA ON-FARM RESEARCH NETWORK

Helping farmers improve, profit.

Helping farmers to improve production practices and increase profitability are goals of the On-Farm Research Network, a part of Nebraska Extension at the University of Nebraska–Lincoln. An early network was established in 1989, with 20 producers from Saunders County who were interested in improving their techniques and profitability. In 2012, the Nebraska On-Farm Research Network was formalized through Nebraska Extension, officially bringing together all the on-farm research programs across the state.

"Any producer, statewide, is invited to be a part of the network," according to Laura Thompson, assistant Extension educator. Interested individuals may visit cropwatch.unl.edu/on-farm-research for more information or to become involved.

Each year, the network conducts about 80 research projects, each widely varying in topic. Research into performance of multi-hybrid planters was conducted in 2016 and 2017; research into seed treatments for sudden-death syndrome (SDS) – a fungal disease in soybean crops – was conducted in 2015 and 2016; and crop canopy sensor research, to measure nitrogen levels in soil was conducted in 2016 and 2017. Every project relates to individual farmers and their interest areas, Thompson said. Separately, each farm's data is recorded, analyzed and presented back to the farmers with results and answers to predetermined questions, with which they can define further action. Each farm's data and final report is catalogued to be viewed in aggregate and by a wider audience, Thompson said, including farmers, agronomists and researchers.

NETWORK RESEARCH

Topic ideas for the on-farm research projects can vary depending on the farmer's interest. Projects range from new product advertisements to new cropping methods, Thompson explained. Another way a project can be developed is through a university researcher or Extension specialist reaching out to farmers with new technological advancements or farming practices. Farmers collaborating with the Nebraska On-Farm

Research Network may be especially interested in new technology and, "trying to see how a new technology may fit in their operation, and what return on investment they might see for using that technology," Thompson said. Two projects in the 2017 season included sudden death syndrome seed treatments and nitrogen management with the use of crop canopy sensors and drones.

SEED TREATMENTS FOR SUDDEN DEATH SYNDROME

In agriculture, sudden death syndrome is a fungus disease, primarily present in soybeans, that produces toxins and kills large numbers of plants. The Nebraska On-Farm Research Network is collaborating with farmers whose fields have evidence of SDS, and are working to eliminate losses with the use of commercially available seed treatments. Aerial imagery will help to determine the treatments' success rates.

"With SDS we know that the disease occurs in pockets throughout the field; by using aerial imagery and looking at specific wavebands, we can gain an understanding of where those hot spots [SDS presence] in the field are, and the response to the seed treatments within those specific areas. This can help us target future seed treatment applications to areas in the field that are most susceptible, which improves efficiency," Thompson said.

PROJECT SENSE – MANAGING NITROGEN

Project SENSE is an ongoing research project focusing on improving nitrogen fertilizer management by using crop canopy sensors to measure properties of the corn crop, Thompson said. SENSE is an acronym for "Sensors for Efficient Nitrogen Use and Stewardship of the Environment," she explained. The project uses crop canopy sensors, mounted on a high-clearance applicator to record plant reflectance. The applicator then applies nitrogen fertilizer in real time, based on varying nitrogen needs within the field.

Research projects conducted in the summer of 2017 used drones to collect information to direct more precise nitrogen management. The drones scanned the fields with multispectral sensors, collecting data from distinctive wavebands related to the nitrogen status of the corn crop. This information was later analyzed and a nitrogen application prescription map was developed based on the corn nitrogen need in various portions of the field.

"Nitrogen management is really important for Nebraska. Using these technologies allows us to apply nitrogen when and where the crop needs it, allowing farmers to be more profitable and productive, while reducing environmental concerns such as nitrate in groundwater," Thompson said.

Once a research project is completed and the data collected and analyzed, all of the information is organized into a final report for the On-Farm Research Network participants. The final reports include site information, objectives, plant types, rainfall data and soil information, as well as a summary of the measurements and data collected. Farmers can use the information in the final reports to accept or reject their research theories about how a product or practice will impact their productivity and profitability. If the data shows they should consider a different management strategy, they will have the data to make any needed adjustments. These final reports and project results are shared not only with the participants, but also at network annual meetings where conversations can begin and new ideas can form.

WHY RESEARCH?

The Nebraska On-Farm Research Network provides farmers the opportunity to lead in a hands-on research experiment tailored to their growing environments.

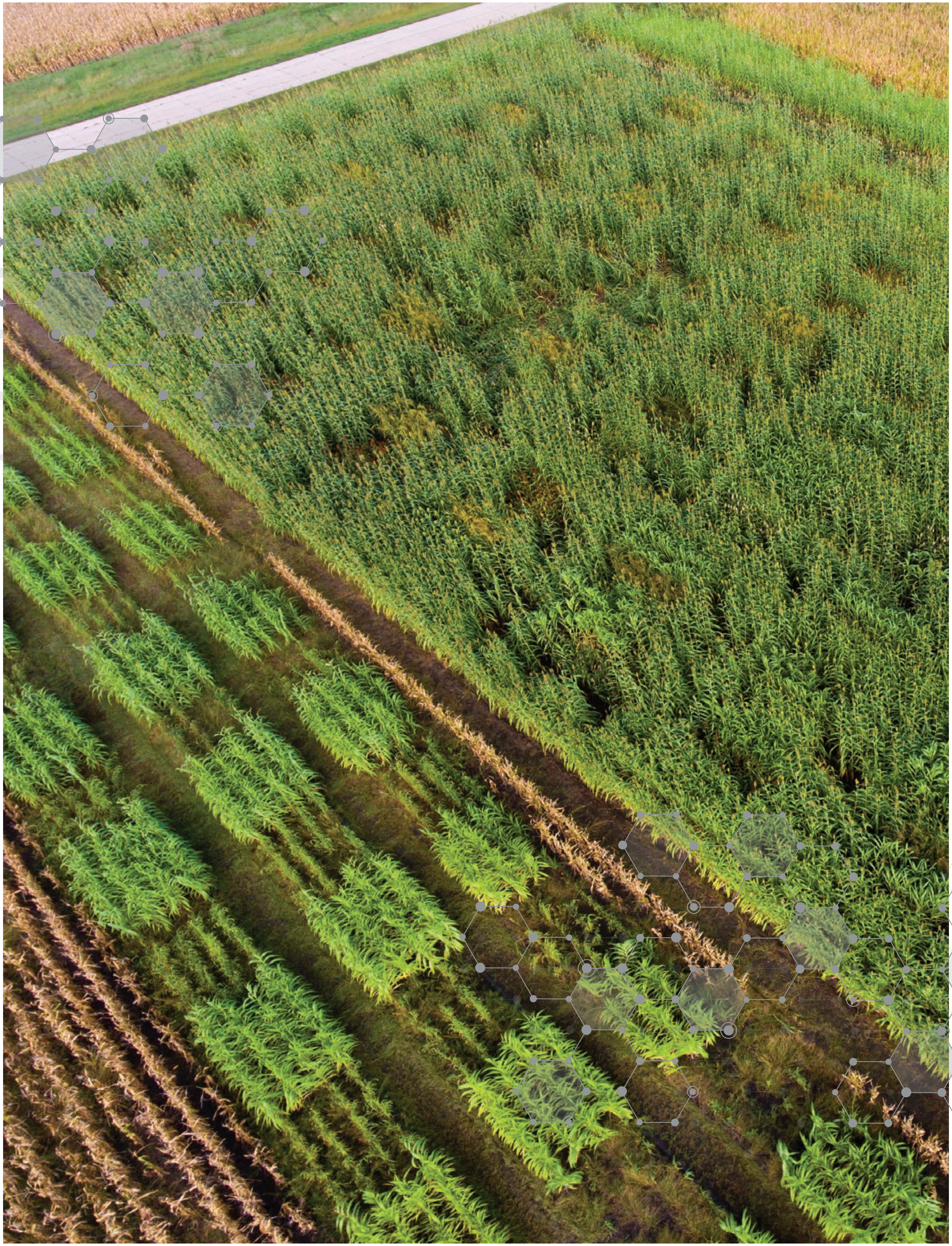
"It is the hope of the network to help guide the producers in making management changes based on accurate and reliable research data, so that they can be confident in their decisions," Thompson said. Through the active participation with the Nebraska On-Farm Research Network, farmers also gain the ability to critically evaluate other production claims and research studies they might discover.

As the producers become more profitable in their practices, others in the state and beyond also benefit, Thompson said. As the agricultural economy grows, so will the state's economy. There also is a positive environmental and sustainability impact that can appear through management practice changes. An example of this is with nitrogen management adjustments, which have the potential to significantly improve groundwater nitrate levels and help to protect water quality for communities in Nebraska.

"I think it really comes down to being able to get actionable insight [recommendations] from the data," Thompson said. "We want producers to use research data and technology to make management decisions that will make them more profitable and productive."

"The goal has always been to make sure we establish good-quality research projects that address real-world issues so we can make contributions to the environment, to people or both."

Suat Irmak



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