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RETAKING THE FIELD

Science Breakthroughs for Thriving Farms and a Healthier Nation

SoAR FOUNDATION

FED BY SCIENCE

"FOOD IS TOO IMPORTANT TO THE HUMAN RACE TO BE A RESEARCH AFTERTHOUGHT."

DR. WILLIAM DANFORTH
CHANCELLOR EMERITUS, WASHINGTON UNIVERSITY IN ST. LOUIS AND SoAR FOUNDER

WE ARE ALL FED BY SCIENCE

Every bite of food you and your family eats is made possible by science. From researchers breeding drought-resistant crops to farmers analyzing data to maximize each drop of water, science makes our food safe, abundant, nutritious, and affordable.

As today's world population of 7.3 billion people grows to a projected nearly 10 billion by 2050, our farmers and ranchers must feed more people with fewer resources at a scale never before seen in human history. Science will allow us to rise to this great challenge, but this critical research depends on increased federal commitments to fund food and agricultural science.

Researchers, professors, and extension specialists are creating and delivering innovative solutions in communities across America. They are making discoveries in their labs, teaching the next generation, and collaborating with farmers and ranchers. Their work provides a healthy food supply and strengthens our economy.

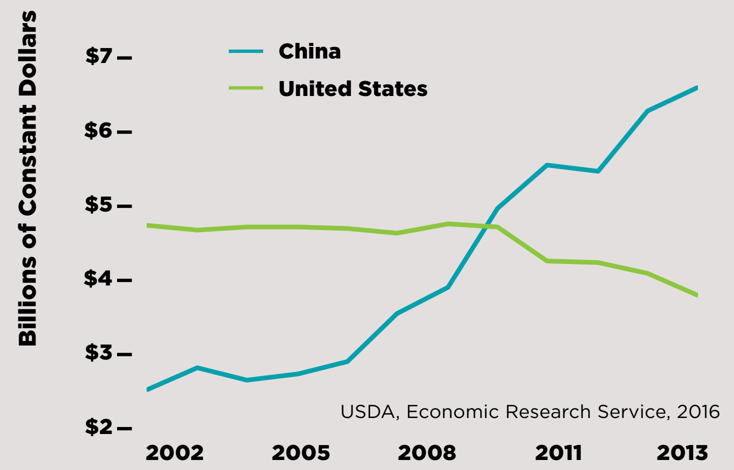
Retaking the Field: Science Breakthroughs for Thriving Farms and a Healthier Nation highlights research within areas identified by the National Academies of Sciences, Engineering, and Medicine that are critical to feeding the world's growing population. This volume features projects from 20 universities in *FedByScience*, a collaborative initiative with the Supporters of Agricultural Research (SoAR) Foundation to raise the visibility of the value of federal and state investment in food and agricultural research.

SCIENCE CAN'T FEED US WITHOUT MORE FUNDING

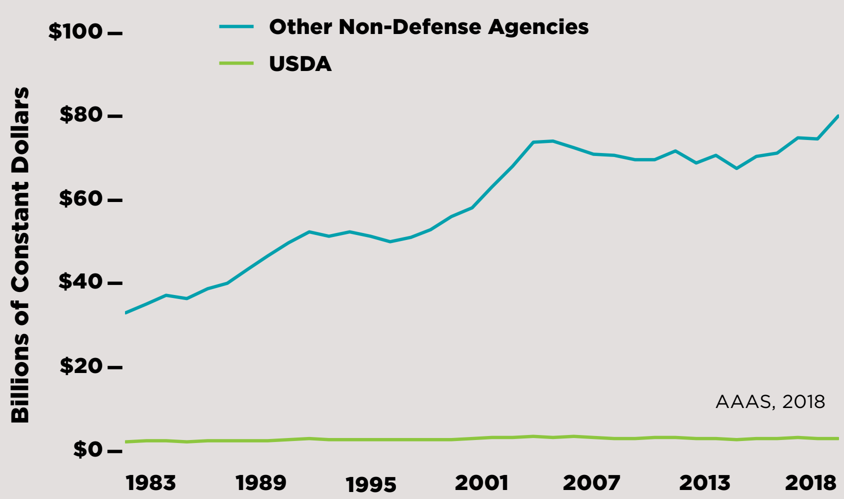
The agriculture sector is critical to the U.S. economy, accounting for nearly $1 trillion of our GDP and 1 in 10 jobs. Agricultural research and development (R&D) funding has an estimated return on investment of 20 to 1. While other federal research investments have grown, U.S. agricultural research funding has stagnated. China invests nearly twice as much as the U.S. in agricultural science.

USDA's National Institute of Food and Agriculture (NIFA) administers federal funding (competitive, capacity, and extension) to address the agricultural issues impacting our daily lives and our nation's future. USDA NIFA is a world leader in funding agricultural research with real-world impact. USDA NIFA invests in cutting-edge research featured in *Retaking the Field*.

Public Ag R&D Spending for U.S. and China 2002-2013



Funding for USDA R&D vs. Other Non-Defense Agencies FY 1983 - 2018



SCIENCE BREAKTHROUGHS FOR FOOD AND AGRICULTURAL RESEARCH

In 2018, The National Academies released its *Science Breakthroughs to Advance Food and Agricultural Research by 2030* report that identifies the greatest scientific opportunities to make the U.S. food and agricultural system more efficient, resilient, and sustainable.

The National Academies used an extensive consensus-building process and incorporated the expertise from nearly 150 researchers in dozens of fields to produce *Science Breakthroughs*. Funders included the SoAR Foundation, the Foundation for Food and Agriculture Research, USDA National Institute of Food and Agriculture, National Science Foundation, US Department of Energy, and 23 other foundations, scientific societies, commodity groups, and associations. The report recommends prioritization of five research areas:

GENOMICS

MICROBIOMES

SENSORS

DATA & INFORMATICS

TRANSDISCIPLINARY

How can Science Breakthroughs build thriving farms and a healthier nation?

In January 2019, representatives from commodity groups, universities, scientific societies, private research institutions, and other organizations met to identify research goals that can only be achieved through advancing the *Science Breakthroughs* priorities. Together, these goals can help ensure two crucial outcomes: **THRIVING FARMS** and a **HEALTHIER NATION**.

THRIVING FARMS are efficient, resilient, sustainable, and profitable. A **HEALTHIER NATION** has broad access to safe, affordable, and nutritious foods. Implementing the *Science Breakthroughs* research priorities will enable our nation to achieve both these outcomes. The goals outlined on the opposite page should drive enormous progress that investments in research will deliver for our nation if appropriately funded.

The *Science Breakthroughs* areas provide a clear roadmap for smart investments that will meet U.S. needs for the next decade of agricultural research. *Retaking the Field* highlights critical research funded by USDA-NIFA that will help America achieve these vital goals through the advancements of *Science Breakthroughs*.

BY 2030, RESEARCH IN THE BREAKTHROUGH AREAS CAN...

REDUCE WATER USE IN AGRICULTURE BY 20%

- Develop more water-efficient crops and livestock using **advanced biotechnology tools**.
- Enhance drought resistance by harnessing naturally-occurring microbial populations (**microbiomes**) to improve soil health and its ability to retain water.

RADICALLY REDUCE THE INCIDENCE OF INFECTIOUS DISEASE EPIDEMICS FOR LIVESTOCK

- Reduce antibiotic use by introducing additional disease resistance traits into major commercial breeds through **advanced biotechnology**.
- Develop probiotics to increase livestock immune function using advances in the animal **microbiome**.

REDUCE FERTILIZER USE BY 15%

- Increase yields by employing naturally occurring soil and plant microbial populations (**microbiomes**) as biological sources of key nutrients.
- Utilize **sensors** and **data-driven** applications for early detection of nutrient deficiencies and field variations.

REDUCE INCIDENCE OF FOODBORNE ILLNESSES BY 50%

- Modify the animal gut **microbiome** to stimulate natural immunity to pathogens.
- Deploy **sensors** to instantly detect the presence of common foodborne pathogens such as *E. coli* and *Salmonella*.

SIGNIFICANTLY REDUCE THE NEED FOR FUNGICIDES AND PESTICIDES IN PLANT PRODUCTION

- Develop disease-resistant crops with **advanced biotechnology tools**.
- Deploy a new generation of **sensors** for swift detection of pests and diseases and **data-driven** management of outbreaks.

INCREASE NEW PLANT VARIETIES AND ANIMAL PRODUCTS WITH ENHANCED NUTRIENT CONTENT

- Use **advanced biotechnology** to develop a wider range of locally-adapted livestock and crops that meet consumer health and producer needs.
- Support **transdisciplinary research** that draws on plant and animal microbiology, human physiology, and plant breeding expertise to develop additional foods benefitting the gut microbiome.

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GENOMICS

HARNESSING THE POTENTIAL OF GENOMICS AND PRECISION BREEDING TO IMPROVE PLANT AND ANIMAL TRAITS.

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EMPLOYING EXISTING SENSORS AND DEVELOPING NEW SENSING TECHNOLOGIES TO ENABLE RAPID DETECTION AND MONITORING.

DATA & INFORMATICS

CAPITALIZING ON INFORMATICS TO ENABLE ADVANCED ANALYTICS USING DATA SCIENCES, INFORMATION TECHNOLOGY, AND ARTIFICIAL INTELLIGENCE.

TRANSDISCIPLINARY

PRIORITIZING TRANSDISCIPLINARY SCIENCE AND SYSTEMS APPROACHES.

GENOMICS

For thousands of years, humans improved crops and livestock by using selective breeding. It used to take generations to breed sweeter corn or larger cattle through a series of best guesses. Even contemporary breeders have to work hard to eliminate undesirable traits, like disease susceptibility or low yield, that may be inherited by offspring together with desirable attributes.

With today's technology, scientists can get better results in a few years rather than a decade. Our deeper understanding of the connection between genes (the hereditary genes in DNA) and phenotypes (physically expressed traits controlled by genes, like the color of your eyes) has led to discoveries in both human health and crop and animal breeding.

The study of genomics takes the science of genetics even further by determining the entire sequence of all of the genes of individuals in a population and examining how slight variations in the sequence among those individuals relate to the expression of different traits. Coupling biology with sophisticated computer analytics, these advances support faster, precise breeding techniques with important impacts on agriculture.

Gene editing tools like CRISPR are now being used in labs across the world to select the gene sequences identified through genomics studies and allow the development of more nutritious crops with improved disease resistance and environmental resilience. They are enabling scientists to add new traits and recover important traits "lost" through centuries of traditional breeding.

USDA NIFA-funded researchers are using the latest technology in genomics and precision breeding to address several challenges in agriculture, from disease prevention in livestock to drought resistance in crops. Breakthroughs in technologies that identify and edit genes will be vital to improving traits important for productivity, efficiency, and resiliency in the coming decades.

How will genomics Breakthroughs create thriving farms and a healthier nation?

- Save orange groves battling citrus greening disease
- Breed wheat with improved enhanced content that requires less water to grow
- Increase disease resistance in pigs, leading to reduced production costs and improved food safety
- Bolster pecan farms by decreasing water and fertilizer use

SAVING CITRUS:

USING GENETICS TO BOOST RESISTANCE TO CITRUS GREENING

UF | UNIVERSITY of FLORIDA

PROBLEM

Citrus greening is spreading rapidly in the U.S. and threatens to destroy our nation's citrus industry.

SOLUTION

By identifying the critical genetic factors that lead to resistance to citrus greening, scientists can breed new varieties that will limit the disease's impact.

RESEARCHERS

Fred Gmitter, PhD, University of Florida
Nian Wang, PhD, University of Florida

FUNDING

USDA NIFA AFRI

Drive through any orange grove in Florida and you are likely to see the blotched yellow stain of disease attacking the very heart of the Sunshine State. Huanglongbing (known as "HLB" or "citrus greening") has infected citrus farms in every Florida county and caused billions of dollars in damage to one of the state's primary crops.

Citrus greening is caused by a bacteria that hitches a ride in a tiny insect, the Asian citrus psyllid. Once infested, trees produce undesirable fruit and slowly decline from a combination of deteriorating roots and tree canopy dieback. There is no known cure for citrus greening.

At the University of Florida's Institute of Food and Agricultural Sciences, researchers are working to save Florida's citrus industry by applying a new gene-editing technique. Known as CRISPR, it allows scientists to speed up the changes that might naturally occur in organisms by editing segments of DNA to achieve a desired outcome, such as improved disease immunity.

When a tree is exposed to the bacteria that causes the disease, it doesn't recognize the threat and instead welcomes the bacteria into its cells. Scientists are seeking an "off switch" in the genome of orange trees that will close its doors to the spread of citrus greening. "Our approach to protect citrus trees against HLB is to increase the potential of citrus' own immunity," said Dr. Wang. With the latest advances in gene editing, the team is helping the orange trees protect themselves to ensure that Florida's citrus industry survives and thrives once again.

Photo credit: University of Florida Institute of Food and Agricultural Sciences

"It has been a joy to witness the explosion in genetic and genomic technology, which has allowed us to achieve accomplishments in my lifetime that we could only dream of at the beginning of my career." – **FRED GMITTER**

Photo credit: University of Florida Institute of Food and Agricultural Sciences

DIVERSIFYING DINNER:

CREATING HYBRID WHEAT FOR IMPROVED PRODUCTIVITY AND NUTRITION

PROBLEM

Wheat is a staple crop that needs to be more productive in the future.

SOLUTION

By developing hybrids in self-pollinated crops, scientists can take advantage of "hybrid vigor" to increase the productivity and nutritional content of wheat.

RESEARCHERS

P. Stephen Baenziger, PhD, University of Nebraska
Vikas Belamkar, PhD, University of Nebraska
Amanda Easterly, PhD, University of Nebraska
Nicholas Garst, University of Nebraska
Hannah Stoll, University of Nebraska

FUNDING

USDA NIFA AFRI
University of Nebraska endowments
Nebraska Wheat Boards/Commissions

Wheat provides 20 percent of the protein and 20 percent of the calories consumed by humans worldwide. When scientists make positive changes in a crop like wheat, it can lift the poorest farmer out of poverty and help feed the 800 million people who go to sleep hungry every night.

Dr. Baenziger and his team are working to recreate the revolution of hybrid corn in wheat. Wheat is a self-pollinated crop, which means it doesn't get a genetic boost by crossing inbred parent lines. The team wants to change wheat from a self-pollinated crop to a cross-pollinated crop to take advantage of "hybrid vigor", a phenomenon that explains why hybrid offspring often have improved grain yield, hardiness, or function compared to its parents.

By developing cross-pollinating hybrids, scientists hope to leverage the natural advantage of hybrid vigor to breed wheat that could have huge advantages such as increased yield, nutrients, and drought tolerance.

Before hybrids are created, researchers must screen existing wheat varieties to identify which strains should be used as parents. Each selected parent strain must be genotyped to map the genes responsible for desired characteristics in the resulting hybrid.

Dr. Baenziger and his team hope their research will breed new wheat hybrids with increased productivity so that farmers can meet the needs of the world's growing population. This research will lead to improved hybrid wheat seed that is affordable for farmers, efficient to grow, and more nutritious for consumers.

"I was a totally urban kid. I read The Population Bomb when I was 17 and thought we must do better than allow millions of people to starve. I became determined to help feed people. Agricultural research allows humanity to thrive."

– STEPHEN BAENZIGER

GENOMICS


Photo credit: University of Nebraska – Lincoln

PROTECTING PORK:

HARNESSING GENOMICS TO IMPROVE LIVESTOCK RESILIENCE

Iowa State University

PROBLEM

Disease is one of the largest threats to pork production and impacts food safety, antimicrobial resistance, and animal welfare.

SOLUTION

Identify biomarkers for disease resilience to breed healthier pigs.

RESEARCHERS

Jack Dekkers, PhD, Iowa State University
Christopher Tuggle, PhD, Iowa State University
Steven Lonergan, PhD, Iowa State University
Graham Plastow, PhD, University of Alberta
Michael Dyck, PhD, University of Alberta

FUNDING

USDA NIFA AFRI
USDA Hatch
Iowa Agriculture Experiment Station
Genome Canada
PigGen Canada

Biosecurity protocols and vaccinations help prevent or reduce disease in pigs, but some animals will still get sick. Disease leads to economic losses for farmers, dangers to food safety, and lowers the animals' quality of life. For instance, porcine reproductive and respiratory syndrome (PRRS) costs the U.S. pork industry an estimated $640 million per year. The annual economic impact of all swine infectious diseases is estimated to be over $1.9 billion.

Some pigs are more naturally resilient, but identifying these pigs is problematic because the swine breeding industry raises their elite breeding animals in high-health farms. To address this, Dr. Dekkers and his international team utilized the swine genome to determine the genetic basis of differences in disease resilience between pigs. To capitalize on the genetics that makes some pigs hardier, the researchers are identifying and targeting unique biomarkers — a naturally occurring gene or molecule serving as a measurable indicator to accurately predict, in this case, disease resilience – that can be measured on healthy, young pigs.

Once pertinent biomarkers are identified, the team will integrate the new genetic knowledge into breeding programs. This will guide future decisions on identifying more disease-resilient pigs to breed the next generation with improved immunity. This will improve swine performance, animal welfare, and food safety, as well as reduce the need for antibiotics on farms.

This project will increase food security and sustainability, while decreasing disease-management costs for producers. The unique collaborations among international scientists and industry partners will allow results to be quickly implemented into breeding programs that impact pork producers across the globe.

Photo credit: Christopher Gannon, Iowa State University

"My childhood dream was to become a veterinarian and I was very intrigued by genetics. My current work allows me to combine these two interests, demonstrating the power of using natural genetic differences to improve animal production and animal welfare." – JACK DEKKERS


Photo credit: USDA-ARS

POWERING PECANS:

LEVERAGING GENETICS TO DEFEND CROPS AGAINST DISEASE AND WEATHER

NM STATE BE BOLD. Shape the Future.
New Mexico State University

PROBLEM

Pecan production is hindered by a number of stresses, including disease, drought, and a challenge known as alternate bearing.

SOLUTION

Develop genetic tools to breed healthier pecan trees that are more productive and resilient.

RESEARCHERS

Jennifer Randall, PhD, New Mexico State University
Richard Heerema, PhD, New Mexico State University
Joe Song, PhD, New Mexico State University
Rolston St.Hiliare, PhD, New Mexico State University
Jay Lillywhite, PhD, New Mexico State University

FUNDING

USDA NIFA Specialty Crop Research Initiative

Pecans are commercially grown across the U.S. American farmers produce nearly 300 million pounds of pecans each year, but the industry is facing mounting challenges from disease, limited resources, and production uncertainty.

Dr. Randall and her team are utilizing the available natural genetic diversity in pecans for future breeding of better seeds. The ultimate goal of the research is to produce trees with specific traits, such as disease resistance and salt tolerance, that will allow for better production. This coordinated effort includes researchers from NMSU, University of Arizona, Noble Foundation, USDA, University of Georgia, Texas A&M, and Hudson-Alpha.

Pecan production is threatened by disease, drought, increasing temperatures, and alternate bearing. Alternate bearing is a cyclical process that causes an individual pecan tree to have a good production year followed by one or more years of poor yield. The bad seasons are greatly affected by drought, disease, and other threats to production.

The research team is sequencing the genomes of four pecan genotypes and has determined what sequences go to which chromosome. This means they are one step closer to understanding which genes lead to optimal characteristics. Selection of pecan crop characteristics will improve by decreasing the time it takes to breed new trees and select desirable traits.

Dr. Randall and her team hope to ultimately develop new pecan varieties that will provide benefits to growers in different regions. New cultivars will be economically beneficial to growers since they will be able to produce a more stable crop with fewer inputs and protect pecans into the future.

"I grew up in a small rural community in northern New Mexico where the importance of agriculture and the need for solutions was apparent. I love plant genetics and that research provides solid and very necessary ways to help farmers."

– JENNIFER RANDALL

Photo credit: New Mexico State University

MICROBIOMES

There are more than a billion microorganisms in a single teaspoon of soil. Human and animal digestive tracts are estimated to contain more than one trillion bacteria and other flora. Despite the staggering numbers associated with various microbiomes, scientists know little about how these trillions of organisms impact us and our food system.

The microbiome – the communities of miniscule organisms like bacteria, fungi, and protozoa found in and on nearly all matter – is a largely unexplored frontier in agricultural science. Microbiomes exists in the soil at our feet, in the crops' roots, on the plants' surfaces, and within the livestock's guts. Each of these microscopic communities impacts how we grow our food, but we are just now beginning to understand the power packed in these tiny organisms.

As we better understand the microbiome, we will be able to harness its power towards improving crop production, transforming feed efficiency, and increasing resilience to stress and disease across our food system. For example, knowing which microbes increase resistance to disease can help tailor diets for cattle, thereby improving animal health and productivity as well as reducing management costs.

NIFA-funded researchers are exploring how the various microbiomes impact efficiency and resiliency in agricultural production. Breakthroughs in microbiomes will be vital to understanding the complex connections among soil, plant, animal, and human health, as well as developing management practices that take advantage of molecular-level interactions within the food we grow.

How will microbiome Breakthroughs create thriving farms and a healthier nation?

- Better connect soil health to improved crop production
- Increase cattle efficiency and improve animal health
- Stimulate the soil microbiome to improve farm efficiency
- Leverage the soil microbiome to fight plant diseases

FORTIFYING FRUIT:

HARNESSING SOIL AND ROOT MICROBIOMES TO BOOST CROP PRODUCTIVITY

PennState

PROBLEM

The long-term viability of fruit crops requires a deeper understanding of how soil microbes and plant roots interact.

SOLUTION

Discover how soil and root microbiomes can be altered to improve plant productivity and soil health.

RESEARCHERS

Michela Centinari, PhD, Penn State
David Eissenstat, PhD, Penn State
Terrence Bell, PhD, Penn State
Suzanne Fleishman, Penn State

FUNDING

USDA NIFA AFRI
Pennsylvania Wine Marketing & Research Program

This Penn State team is working to better understand how soil microbes and plant roots interact in order to provide new tools that maximize production, improve soil health, and reduce the use of agrochemicals.

Farmers have long-term investments in perennial fruit crops, and it is important to adopt management practices that avoid or delay productivity declines. For example, most orchards and vineyards, formerly maintained as monocultures, now include annual or perennial cover crops. The cover crops improve the soil's physical and chemical properties. Less is known, however, on how cover crops impact the soil microbiome and interact with the roots of woody fruit crops. These organisms can be critical to long-term soil and crop health, and sustainable productivity.

The team established a multi-year field study to evaluate how cover crop use might change the abundance and composition of microorganisms associated with grapevine roots. Roots, an important but typically hidden half of the plant, have a complex relationship with the soil microbiome surrounding them that is not yet fully understood.

The researchers are also helping scientists refine techniques for sampling soil and roots. Soil is often sampled without detailed consideration of surrounding root characteristics, which leaves out a vital component to understanding how the soil microbiome impacts plant health.

By learning to optimize the interactions in the soil and root microbiomes, this project will help limit the future need for fertilizers and pesticides, promote environmentally responsible management practices, and improve the long-term economic viability of fruit crop production.

Photo credit: Penn State

"I grew up in Italy in a region where the wine industry is hundreds of years old. In high school, I helped local growers during harvest. I am fascinated by the passion, creativity, and persistence of growers as they work to improve wine quality." – MICHELA CENTINARI

Photo credit: Penn State

MAXIMIZING MICROBES:

IMPROVING FEED EFFICIENCY AND NUTRITION FOR SUSTAINABLE BEEF

INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

PROBLEM

Researchers cannot account for all the variation contributing to feed efficiency in beef cattle, limiting advances in sustainable beef production.

SOLUTION

Capitalize on a deeper understanding of the role that the gut microbiome plays in how cattle process feed.

RESEARCHERS

Phillip Myer, PhD, University of Tennessee
Liesel Schneider, PhD, University of Tennessee
Kristin Hales, PhD, USDA
Jim Wells, PhD, USDA
Students

FUNDING

USDA NIFA Hatch/Multi-state
Ascus Biosciences
PharmaCare Laboratories
University of Tennessee Institute of Agriculture
AgResearch
UTIA Sustainable Beef Initiative
University of Tennessee

The world's population is expected to exceed 10 billion people by 2050. To supply the growing population with adequate sources of protein, food production must continue to improve efficiency.

Dr. Myer and his team work on this complex challenge by improving the nutrition and feed efficiency of beef cattle. To do so, they are developing tools and technologies that examine the rumen and gut microbiome. They are also identifying relationships among an animal's microbiomes with its diet, physiology, and genetics to understand how these factors impact feed efficiency.

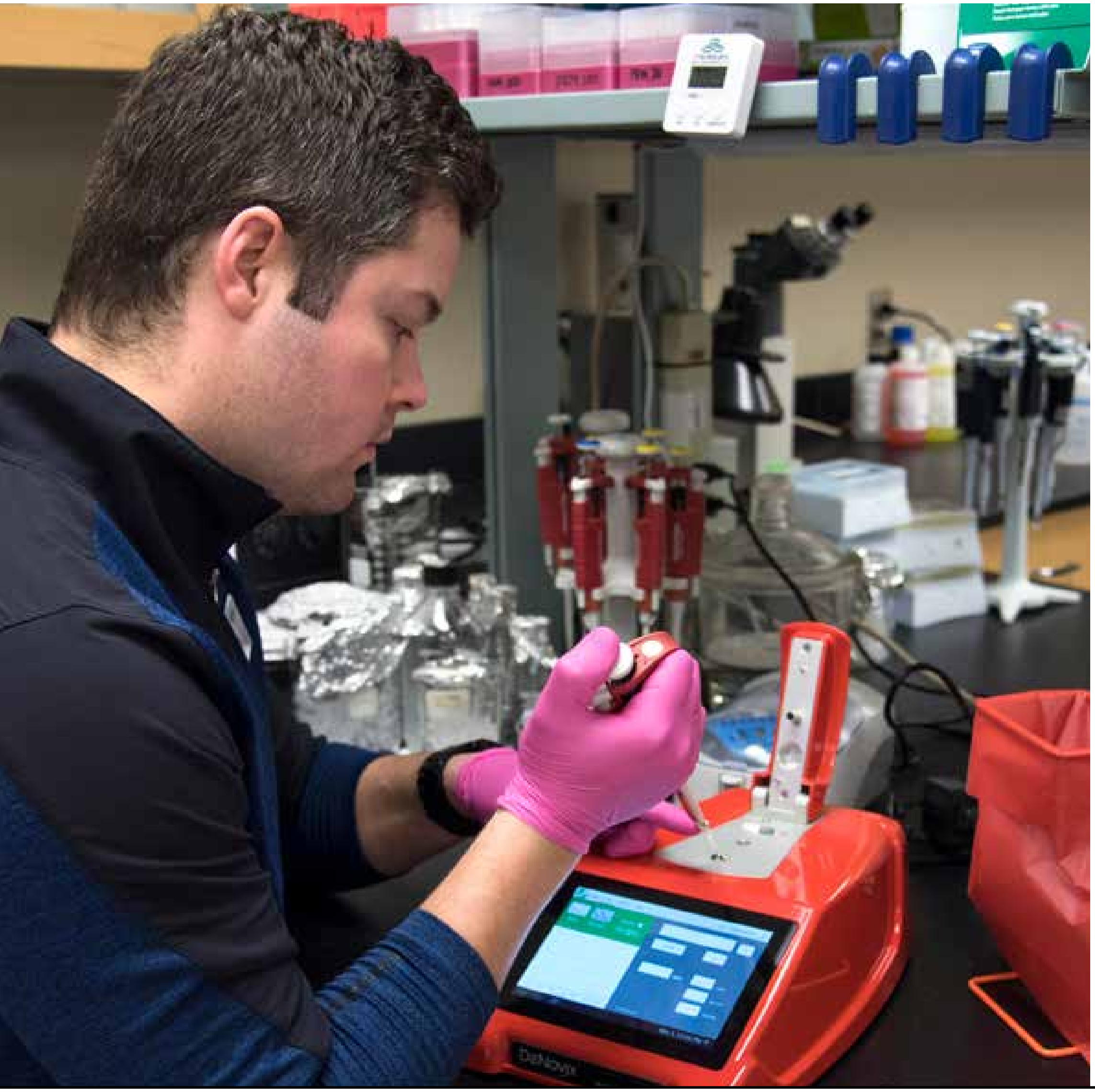
The rumen is the first compartment of the stomach in cattle and operates as a complex fermentation chamber colonized by numerous microbial species. These microbes act together to convert plant material into nutrients, which are ultimately transformed into protein fit for human consumption.

Optimizing or modifying the microbial community in the gut stands to significantly improve the way cattle absorb nutrients. The research team's current data suggest that specific microbes may be functionally more important than others in determining the differences between high and low feed efficient cattle.

The next step for Dr. Myer and his program is to determine to what degree the rumen microbiome influences animal health and vice versa, and to connect this understanding with the cattle's genome.

As producers and researchers work to optimize cattle productivity, these combined microbiome and genomic tools could improve selection for feed efficient cattle. This will help secure high-quality sources of protein for the growing global population in the coming decades.

Photo credit: University of Tennessee, Institute of Agriculture



"Microbes equal or outnumber cells throughout the body. By learning more about the mutually beneficial relationships among ruminant hosts and their microbes, we can have a great impact on the beef industry. I'm excited that our research will help feed future generations."

– PHILLIP MYER

Photo credit: University of Tennessee, Institute of Agriculture

REJUVENATING RESOURCES:

WORKING WITH FARMERS TO IMPROVE SOIL HEALTH

UC DAVIS
UNIVERSITY OF CALIFORNIA

PROBLEM

The quantity and quality of our soils is degrading, which reduces farm productivity.

SOLUTION

Rebuild and improve the health of soils by targeting the microbiome.

RESEARCHERS

Kate Scow, PhD, UC Davis
Nicole Tautges, PhD, UC Davis

FUNDING

USDA NIFA AFRI
USDA NIFA Hatch
State of California
University of California

Healthy crops depend upon healthy soil. Dr. Scow leads a multi-disciplinary team of researchers working at UC Davis' Russell Ranch Sustainable Agriculture Facility and in farmers' fields. Their goal is to build a more resilient and regenerative agricultural system by paying attention to what is happening below ground.

Life abounds in soil, yet it is often neglected. The soil is where unseen communities drive numerous ecological processes - energy flow, nutrient cycling, waste removal - essential for growing our food. The team is working to understand the role of the soil microbiome in creating productive soils. They investigate interactions among microorganisms, the soil's physical-chemical environment, and the substances that flow through them.

They are mapping the composition, functions, and relationships among species in soil to better understand what they need to flourish. The aim is to have soil that is robust enough to survive droughts, attacks from pathogens, and other stressors.

The researchers are already moving beyond the lab. Their various interconnected studies include work in the greenhouses, farmers' fields, throughout farmer networks, and include both short and long-term field trials.

Dr. Scow and her team cultivate partnerships and collaborate with farmers to support regenerated soil and thriving farms. Together, they develop management practices that enhance the soil microbiome and promote healthy soils. They disseminate guidance on new approaches for growers to apply in their fields. By regenerating and building more resilient agricultural systems, this research helps farmers increase their productivity today and preserve soil for future generations.

Photo credit: Gregory Urquiaga, UC Davis

"I fell in love with soil. It is a living, precious, complex, and mysterious resource that takes centuries to form and can be lost in a blink of an eye. There is amazing diversity under our feet. Soil is alive!"

– KATE SCOW

APPLYING ALTERNATIVES:

LEVERAGING THE SOIL MICROBIOME TO FIGHT DISEASE

KANSAS STATE UNIVERSITY

PROBLEM

Soilborne diseases reduce crop yield and quality and can devastate crops.

SOLUTION

Develop new methods of improving soil health to combat disease.

RESEARCHERS

Gretchen Sassenrath, PhD, Kansas State University
Chris Little, PhD, Kansas State University
Xiaomao Lin, PhD, Kansas State University
Kraig Roozeboom, PhD, Kansas State University

FUNDING

Kansas Soybean Commission
Kansas Crop Improvement Association
USDA NIFA Hatch

Charcoal rot is a soilborne disease caused by a fungus (Macrophomina phaseolina) that results in significant crop losses. At Kansas State University, a team of researchers quantified the presence of charcoal rot disease in soybeans and have developed alternative management practices to address the disease.

The team planted a mustard cover crop that reduced charcoal rot disease in soybeans. Significantly fewer pathogen colony forming units (CFUs) were observed in both the soil and plants from the treated compared to the control plots. The method of managing the cover crop also had a substantial impact. Tillage increased levels of the charcoal rot fungus, but no-till planting directly into a standing mustard cover crop reduced pathogen CFUs.

"I am passionately curious to understand how things work. My research has evolved to integrate my understanding of crop production into holistic aspects of how the world works. By understanding how nature works, we can build a better environment."

— GRETCHEN SASSENRATH

A surprising finding is that individual cultivars have different impacts on their environment. Two cultivars had different soil microbiological activity. This indicates that different cultivars of the same species interact with the soil to create a unique soil microbiome.

Photo credit: Tommy Theis, Kansas State University

As a result of the team's outreach, farmers have begun using mustard cover crops in their fields to reduce charcoal rot disease. The research is also developing standard protocols for farmers to incorporate cover crops into standard production. This may be a simple method of controlling soilborne diseases while reducing fungicides that can be harmful to the environment.

This research impacts our understanding of how crop diseases can be controlled and managed. Changing the soil microbiome may allow us to improve plant health, food safety, and public health.

Photo credit: Kansas State University

SENSORS

The future of agriculture is precise, customized management of production down to each individual plant and animal. This agricultural revolution requires coordinated efforts to advance sensor technologies that can be deployed in the field and managed from a central location. Farmers can use sensors in conjunction with robotics, drones, and other monitoring systems that provide information to inform management decisions.

Advances in nanotechnology prepared the way for a new breed of biosensors that can help farmers and food distributors improve efficiency and safety in agriculture. Improvements in sensors can help farmers use less water, fertilizers, and pesticides by allowing them to determine the precise requirements of their crops and livestock.

Biosensors can act as "cyber canaries" in the field by alerting farmers to a variety of changes in crops, from pest or pathogen infestations to changing water levels. Similarly, improved sensors can help distributors detect when food has spoiled or been contaminated by foodborne pathogens.

The information provided by diverse arrays of sensors facilitates a transdisciplinary approach to understanding the outcomes of interactions of different influences on the food system, from weather to human behaviors. Analyzing the gathered data is key to unlocking the power of sensing technology to increase the efficiency and sustainability of agricultural production.

USDA NIFA-funded researchers are utilizing the latest in sensing technology to allow precise control over inputs (e.g., water, fertilizer), better management of pests and pathogens, and quicker breeding selection for improved varieties.

How will sensor Breakthroughs create thriving farms and a healthier nation?

- Precisely manage inputs, such as water and fertilizer
- Detect risks of foodborne pathogens in real-time
- Reduce water use in a variety of crops

DEPLOYING DRONES:

HELPING FARMERS UTILIZE NEW TECHNOLOGY TO IMPROVE EFFICIENCY

FORT VALLEY STATE UNIVERSITY

PROBLEM

Farmers want to capitalize on new technologies to make farming more efficient but need more training to integrate it into their current systems.

SOLUTION

Collaborate and train farmers to determine how drone technology can provide them with direct benefits.

RESEARCHERS

Archie Williams, PhD, FVSU
Cedric Ogden, PhD, FVSU
Graduate and undergraduate students, FVSU

FUNDING

USDA NIFA Evans-Allen

Drone technology can be a powerful decision-making tool for farmers and provide a low-cost alternative to improve their efficiency and bottom line.

Dr. Williams and his colleagues at Fort Valley State University (FVSU) are "bridging-the-gap" of information between drones' technological advances and farmers' needs and expectations. In this way, the "pretty pictures" produced by drones become useful information for farmers.

The FVSU team is developing experimental and data collection procedures for agricultural unmanned aerial vehicle (UAV) applications and evaluating how well the UAV can identify problem areas on farms.

"As a child, I dissected my toys to figure out how they worked. My parents joked that they prayed I would learn to put things back together. They knew early on that I would become an engineer. I am still tinkering."

– ARCHIE WILLIAMS

Researchers collaborate with farmers to learn their views on what is the most important information they need to improve production efficiencies. The team evaluates what drones can detect and record, then determine how this data can be presented in the best format for producers.

The team teaches farmers how to take fuller advantage of drone technology for practical applications. For example, they provide basic hands-on training using a software that maps out crops and locates areas

Photo credit: Latasha Ford, Fort Valley State University

that may need additional fertilizer or treatment. In this way, farmers can obtain information that applies specifically to crops they are growing on their land.

This research and outreach can make farmers' production more efficient and sustainable. It helps farmers optimize inputs (e.g. time, money, labor, equipment, chemicals) and maximize productivity including yield and profits.

USDA NIFA's funding is essential for this project and enables FVSU to involve students in firsthand research, which broadens their horizons on the future of agricultural engineering technology.

Photo credit: Latasha Ford, Fort Valley State University

SENSING SAFETY:

DEPLOYING SENSORS TO SAFEGUARD THE FOOD SUPPLY

NC STATE UNIVERSITY

PROBLEM

Foodborne illness is a major public health challenge.

SOLUTION

Develop new sensors that detect pathogens and alert farmers in real time to reduce the threat of foodborne illnesses.

RESEARCHERS

Ralph Dean, PhD, NC State University
Sophia Kathaiou, PhD, NC State University
Omer Oralkan, PhD, NC State University
Greg Parsons, PhD, NC State University

FUNDING

NC State Agricultural and Life Sciences Research Foundation
USDA NIFA Hatch

Foodborne illnesses are a major public health challenge resulting in 3,000 deaths each year and costing our nation an estimated $15.6 billion annually. To protect people and reduce the costs, researchers at North Carolina State University are working to keep certain disease-causing microorganisms out of the food supply entirely. Engineers, plant scientists, and food microbiologists collaborate to develop electronic sensors that alert farmers right away when these microbes are present.

Sparked by NC State's Plant Sciences Initiative, the team is making rapid progress. Over the past two years, it has created small, affordable, and reliable sensors that can detect and diagnose insect attacks so fast that farmers have time to prevent crop loss. Now, with funding from the USDA NIFA, microbiologist Sophia Kathariou is guiding an effort to determine whether the technology can be adapted to detect foodborne pathogens like *Salmonella, E. coli*, and *Listeria* in fresh produce.

Photo credit: North Carolina State University

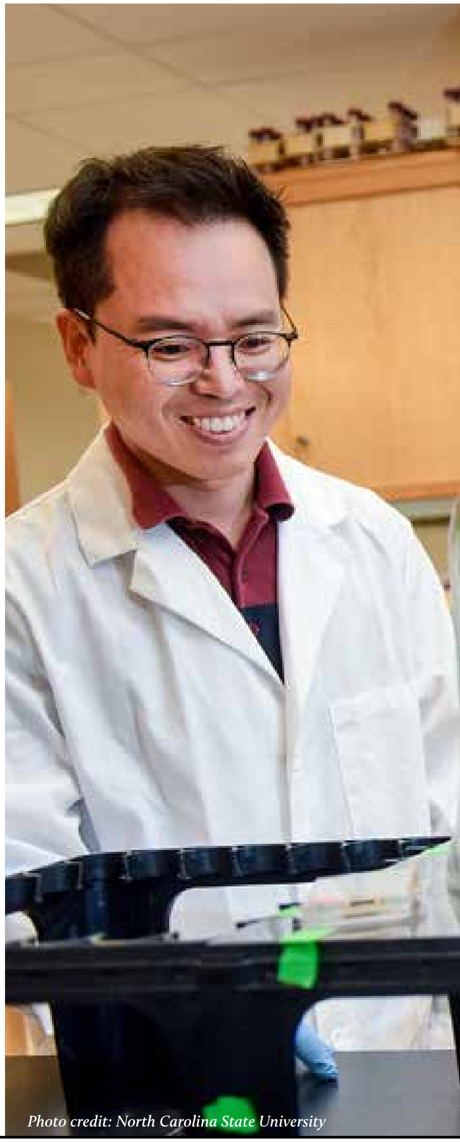


Photo credit: North Carolina State University

Developed under the leadership of plant pathologist Ralph Dean and engineers Omer Oralkan and Greg Parsons, the initial technology was funded by the North Carolina Agricultural and Life Sciences Research Foundation. It works by detecting volatile organic compounds, or VOCs, that plants emit when they are under stress. Each type of stressor emits a distinct bouquet of VOCs, and the sensor-array technology is designed to pinpoint that specific stressor.

The effort is part of a much larger, multidisciplinary project involving scientists from agencies and universities nationwide. Its goal is to provide novel tools and information that lower public health risks associated with major human pathogens.

"Our research to understand plant stress in real time is like searching for the Holy Grail. We can't wait until a plant is sick or being attacked. We want to be able to identify those plants immediately so we can stop the problem before it starts."

– RALPH DEAN

IMPROVING IRRIGATION:

DEVELOPING SENSORS TO MEASURE THIRST IN PLANTS

Cornell University

PROBLEM

Producers have access to precision irrigation tools, but can't use them to their full potential without better plant measurements.

SOLUTION

Enable farmers to more precisely manage irrigation by developing sensors that measure the water use of individual plants.

RESEARCHERS

Abe Stroock, PhD, Cornell University
Michael Santiago, PhD, Cornell University
Alan Lakso, PhD, Cornell University

FUNDING

USDA NIFA Hatch

Agriculture accounts for 70 percent of freshwater use worldwide. To feed the world's growing population, farmers must make the most of each droplet.

There are many precision irrigation tools available for farmers, but there are few ways to know exactly how much water individual plants need. Plants, just like people, get thirsty and need the right amount of water to thrive.

Thirsty plants have stunted growth, lower disease resistance, and produce less fruit and grain. At the same time, overwatering can reduce the quality and even kill crops. The trick is finding a "Goldilocks Spot" where the water quantity isn't too high or too low, but just the right amount for each individual plant.

Dr. Stroock and his team are developing sensors to detect the thirst of apple trees in order to more precisely irrigate orchards. Instead of using traditional techniques to estimate water needs through weather and soil conditions, researchers are asking the plant directly by gathering continuous data through sensors embedded in tree trunks.

These sensors transmit data to a central location where researchers analyze how the plants consume water. Once the thirst mechanism in apple trees is better understood, the team will develop a tool that translates the sensor data into usable information to help farmers optimize water use.

By reducing water use on specialty crop farms and lowering the downstream impact of runoff from over irrigation, this work will also help farmers lower input costs and increase the quality and value of crops.

"When I visited the redwood forest in California in my youth, I was inspired by the natural feat of engineering. I wanted to understand how trees 350 feet tall could pump water from its roots up into its leaves. My research harnesses the power of nature."

– ABE STROOCK

Photo credit: Cornell University

SOFTWARE FOR SOYBEANS:

USING DRONE TECHNOLOGY AND COMPUTER ANALYSIS TO EVALUATE NEW PLANT VARIETIES

PURDUE UNIVERSITY

PROBLEM

Assessing the traits of new soybean plants by hand is a laborious method plant breeders use to evaluate new cultivars.

SOLUTION

Develop software tools that can analyze soybean characteristics based on overhead footage captured by drones.

RESEARCHERS

Katy Martin Rainey, PhD, Purdue University
Keith Cherkauer, PhD, Purdue University

FUNDING

USDA NIFA AFRI

The world's population is expected to near 10 billion people by 2050, and today's agricultural production is not sufficient to feed them all. Crop yields will need to increase and breeders will have to develop new plants that are more tolerant of heat and drought, both of which are expected to increase as the global climate changes.

To evaluate potential new crop varieties, breeders must plant them in test plots and record data on traits by hand in order to "phenotype" them. Phenotyping is categorizing the physical and biological traits of a plant, such as leaf density or fruit quality, in order to connect desired characteristics to the plant's genetics. This laborious process may be required for hundreds or thousands of plants multiple times per year. The data recorded, such as plant color, may be subjective based on who is making the measurement.

Dr. Rainey and Dr. Cherkauer are automating these processes in soybeans. Drones fly over test plots and record high-resolution photos in a fraction of the time that it would take people to phenotype by hand. The photos are analyzed to gather many measurements that breeders need, such as row length, canopy coverage, and plant color.

The software analyzes geo-referenced pixels from the photos. That technology is simple, yet robust, and high-level data can be obtained from off-the-shelf drone and camera products for only a few hundred dollars. These tools make breeding more efficient and less expensive, increasing the pace of advances to feed a growing global population.

"Drones have become more accessible and inexpensive, but there's a need to understand how to use them in the breeding pipeline. There's a lot of intellectual creativity in this work, and that has always attracted me to science."

– KATY MARTIN RAINEY

Photo credit: Purdue University Agriculture

DATA & INFORMATICS

More data was created in the last two years than in the entirety of human history. In the food and agriculture arena, there is more data available than ever before. This data is created by sensors in fields, genetic analyses in labs, predictive weather models, and hundreds of other inputs. But the data collected comes in a variety of forms on a wide range of software platforms that aren't coordinated with each other.

Managing and using this flood of information is key to solving some of agriculture's most pressing challenges. Informatics is the intersection of data science, software developments, and systems modeling that allows scientists to take a deluge of data and build a fountain of knowledge.

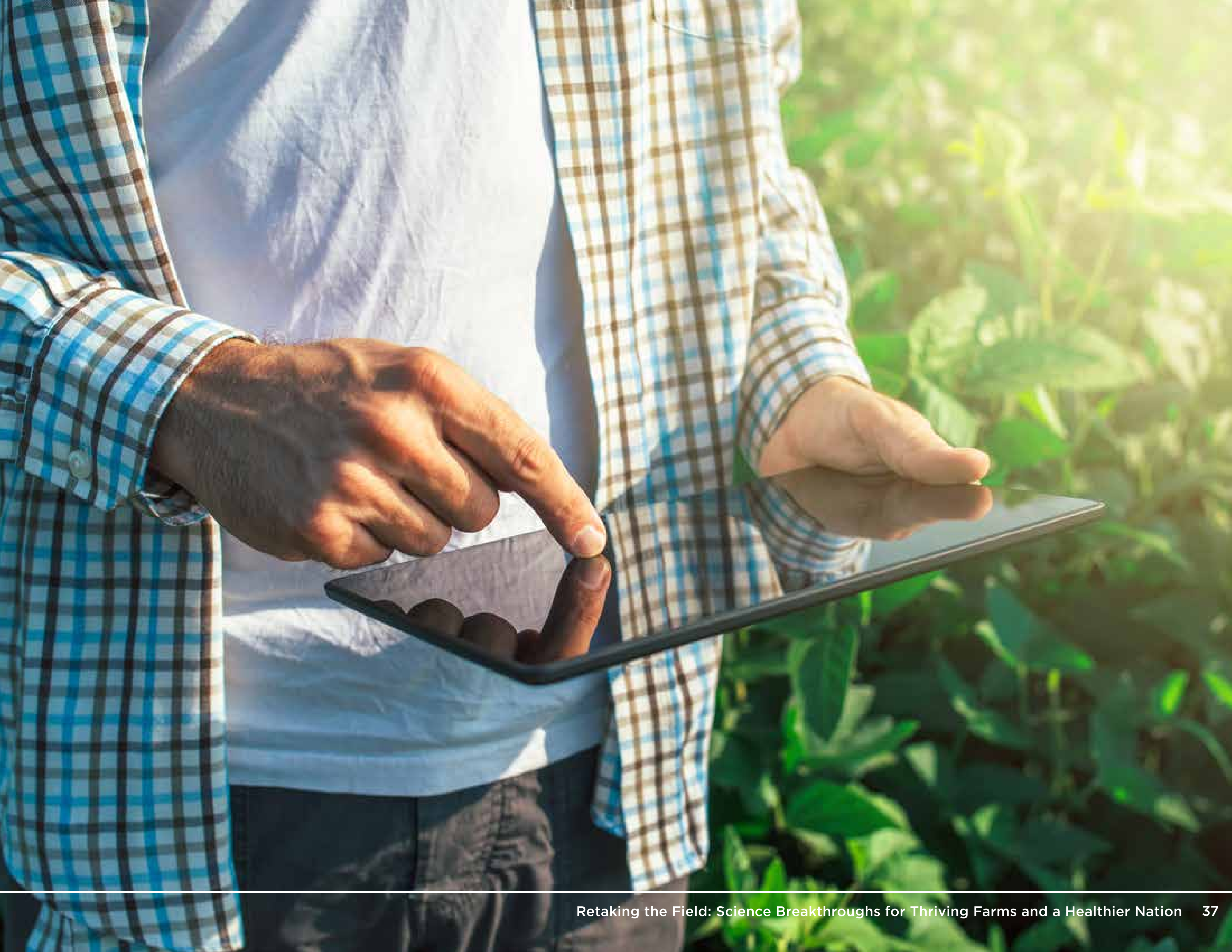
Diverse research teams are bringing together the best and brightest minds in agriculture, data science, and computer science to equip farmers and ranchers with the right tools to collect, manage, interpret, and utilize data.

Entire growing seasons can now be simulated with computers using a combination of genetic information, climate predictions, and on-farm management practices. Today, we can harness the power of computer science and data analytics to save years of testing new crops in the field and deploy customized solutions for farmers in real-time.

NIFA-funded researchers are using the latest breakthroughs in agri-informatics to help farmers and ranchers accomplish more with data. Complex problems can now have data-driven solutions that make farms more efficient as they strive to grow more with less resources and environmental impacts

How will data and informatics Breakthroughs create thriving farms and a healthier nation?

- Make farms more efficient by using data-driven decisions to manage water and fertilizer application
- Improve breeding by analyzing plant and animal genetics
- Integrate on-farm data to provide individualized diets for livestock
- Help farmers make planting decisions that increase efficiency



PROMOTING PRECISION:

USING SATELLITE DATA TO MANAGE WATER AND FERTILIZER USE

Colorado State University

PROBLEM
Traditional application of crop inputs, like water and fertilizer, can be inefficient and lead to losses.

SOLUTION
Create precision management techniques for nitrogen and water that will minimize environmental impacts and maximize farm efficiency.

RESEARCHERS

Raj Khosla, PhD, Colorado State University
Louis Longhamps, PhD, Colorado State University
Robin Reich, PhD, Colorado State University

FUNDING

USDA NIFA Hatch
NRCS
EPA
NASA
Private industries
Colorado Corn
Agriculture Experiment Stations and Cooperative Extension

Traditionally, farmers apply crop inputs uniformly across the field – a "one-size-fits-all" approach. This leads to parts of the field with over- and under-application of water and nitrogen, which is a major concern for the environmental impact of agriculture.

Dr. Khosla and his team are reducing water and nitrogen use by enhancing the efficiency, productivity, profitability, and sustainability of crop production systems through informatics. Farmers can only manage what they can measure, and informatics can help them make sense of what they are measuring. The team employs the "Five–R" principles of precision agriculture: Applying the right input, at the right time, at the right place, in the right amount, and in the right manner.

"When I was in 4th grade, I participated in the science fair at our school and a science program at our local radio station. This inspired me and fostered my interest in science, plants, and biology. My professors helped turn that curiosity into my passion."

– RAJ KHOSLA

By developing precision management techniques, researchers aim to minimize nitrogen and water losses without reducing yield. The team developed an innovative technique of measuring the variability of soils across a field using satellite-based remote-sensing technology to create management zones, which is currently used by farmers across Colorado,

Photo credit: Colorado State University

the U.S., and the world. The team uses advanced analytics to decipher the data gathered and develop data-based management tools for farmers.

The team's next goal is to detail the economic advantages of adopting precision agriculture so farmers know how their investments will pay out. One study already showed that with precision nitrogen management, farmers can earn an additional $17 per acre compared to traditional management practices. Dr. Khosla's team hopes to show even larger gains for farmers who switch to their data-driven management system.


Photo credit: Colorado State University

ELEVATING EVALUATION:

DEVELOPING NEW TOOLS TO UNDERSTAND ANIMAL GENETICS

UNIVERSITY OF GEORGIA

PROBLEM

Animal genetics are complex and current breeding techniques are prone to errors or weak results.

SOLUTION

By understanding genetic relationships, breeders can better select for desired traits.

RESEARCHERS

Ignacy Misztal, PhD, University of Georgia
Daniela Lourenco, PhD, University of Georgia
Ivan Pocrnic, PhD, University of Georgia
Graduate students

FUNDING

USDA NIFA AFRI
Holstein Association
Angus Association
Zoetis
Cobb-Vantress
Pig Improvement Company
Smithfield
DNA Genetics
Maschoff's

Farmers and commercial breeders constantly search for the best animals to breed for dairy, beef, and poultry production. This selection process is often based on pedigree and physical evaluation of desired traits, but this method is prone to error and doesn't always lead to better traits.

An animal's DNA can contain 3 billion data points, presenting an immense challenge to selecting animals based on genetics. Analysis is often limited due to the costs of computing the data, weaknesses in pedigree evaluation, and the complexity of genetic relationships that result in desired traits.

Dr. Misztal and a team of international researchers are working to solve this problem by simplifying genetic analyses for dairy cattle evaluation. Using data from more than 3 million Holstein cows, the team examined genetic relationships within the cattle genome that led to desired traits, such as increased milk production.

Researchers were able to simplify the analysis into a single-step process that provides a more accurate prediction of genetic potential in breeding animals.

This project will provide a reliable, accurate, fast, and easy-to-use tool for genomic evaluation of animals in the U.S. dairy industry, with no restrictions on the number of phenotypes, pedigree, and genotypes that can be studied. This will allow breeders to develop well-balanced cows that grow fast, give plenty of milk, reproduce efficiently, and resist disease.

"When consumers buy meat or dairy products, there is a greater than 70 percent chance that the product comes from animals selected using our genetic and computational methods. I am proud of the discovery and development of accurate, simpler, and powerful methods for genetic evaluation."

– IGNACY MISZTAL

Photo credit: Andrew Davis Tucker, University of Georgia

REINFORCING RESILIENCE:

LEVERAGING SUPER COMPUTERS TO PREDICT CROP YIELDS AND WATER REQUIREMENTS

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PROBLEM
Global climate change is projected to impact crop productivity, but it's not clear how changes in temperature will affect plants.

SOLUTION
By better understanding the impacts of temperature changes on crops, scientists can help inform breeders as they select more resilient traits.

RESEARCHERS
Kaiyu Guan, PhD, University of Illinois
Carl Bernacchi, PhD, University of Illinois
Elizabeth Ainsworth, PhD, University of Illinois
Bin Peng, PhD, University of Illinois

FUNDING
USDA NIFA AFRI
NASA New Investigator Award

Dr. Guan and his team use computer modeling to determine how increasing temperatures impact soybean growth and crop production. This enables them to more accurately predict the future impacts of a changing climate on agricultural production and identify promising targets for adaptation.

Dr. Guan leads a project that analyzes how temperature affects major plant processes such as photosynthesis and respiration in soybeans. The team is combining the temperature free-air controlled enhancement (T-FACE) experiment through University of Illinois' SoyFACE facility and a newly developed crop-modeling framework.

One typical class of crop models is agronomy-based, which involves various soil and crop management techniques. Another involves climate models that predict reactions to temperature and other weather variables. They are developed for different purposes and applied at different scales. When used together, they create a new model with improved predictive power. The team's goal is to combine the two approaches into a single tool that can better evaluate soybean varieties.

To test the new model, infrared heating arrays produce heat stress on three soybean varieties, representing the major groups planted across the Midwest, for two growing seasons. Multiple physiological and biochemical measurements are taken simultaneously. This data is merged into the new computer simulation to model plant reactions to higher temperatures.

The team will apply the new model in test fields to predict the impacts of various climate scenarios on farms in the Corn Belt. These results will help crop breeders select traits to make future crops more efficient and resilient in the face of rising global temperatures.

"I have a dream that moving forward, we will be able to monitor every field on this planet. We will know crop conditions, yields, and most importantly how much water and fertilizer the crops require. Our research is progressing in that direction."

– KAIYU GUAN

Photo credit: University of Illinois

FEEDING FARM ANIMALS:

USING COMPUTING TECHNOLOGY TO INDIVIDUALIZE DIETS

PROBLEM
To meet the demands of a rapidly growing world, animal agriculture must continue becoming more efficient.

SOLUTION
Develop and deploy cutting-edge technologies to inform decision-making in animal agriculture.

RESEARCHERS
Robin White, PhD, Virginia Tech
Richard Voyles, PhD, Purdue University
Shashank Priya, PhD, Penn State University

FUNDING
USDA NIFA AFRI

Precision animal agriculture is a new and largely unexplored area that is expected to have transformative, positive impacts on livestock production. Scientists and producers are challenged with treating both the individuals and the collective herd in addressing nutrition, health, and productivity. Individual animals are complex and require constant nutritional adjustment. They are also social animals with herd behaviors that impact feed consumption.

At Virginia Tech College of Agriculture and Life Sciences, Dr. White focuses on precision animal nutrition to improve livestock health and the efficiency of food production. Her team explores how the nexus of a specific animal's behavior (e.g., how the animal responds to different types of feed) and collective herd behavior (e.g., how the cows spend time eating and resting together) impact efficiency.

To advance the science needed to create and implement customized diets, the team is developing novel sensors (e.g., miniaturized robots to sample the animals' guts). They are testing new networking technologies that address the challenge of transmitting data around the farm and are creating new farm-scale technologies such as robotic feeders. They plan to show how all of these technologies can be integrated to inform decision making through a "demonstration farm".

While Dr. White and her team work with dairy cows, their technology could be applied to other animals. These researchers are developing a more efficient system that creates healthier animals, lessens environmental impacts, and reduces costs for producers. There is tremendous economic potential in expanding and industrializing these new technologies.

"I find the challenge of how to feed our growing population to be among my generation's most important questions. Agriculture is a vastly complicated web of interactions. In a world focused on black and white, solutions are often shades of grey."

– ROBIN WHITE

Photo credit: Virginia Tech College of Agriculture and Life Sciences

DECIPHERING DECISIONS:

USING DIGITAL TOOLS TO HELP FARMERS PLANT THE RIGHT SEEDS

Washington University in St. Louis

PROBLEM

Farmers need guidance to select the optimal seeds based on varying planting conditions.

SOLUTION

Using machine learning, analyze how soybean varieties respond to environmental stresses to help farmers make better planting decisions.

RESEARCHERS

Lingxiu Dong, PhD, Washington University in St. Louis

Durai Sundaramoorthi, PhD, Washington University in St. Louis

FUNDING

Washington University in St. Louis

Today, farmers are inundated with seed choices for annual planting. They must choose from hundreds of varieties that have been optimized by seed companies to succeed in specific conditions. For example, one seed might be very good for early planting but not as high-yielding if rain delays planting. Others offer improved resistance to pests or require less water to grow.

Researchers at Washington University in St. Louis are using machine learning to help farmers make informed planting decisions. The computational models allow farmers to receive the top five recommendations for seeds in a given season based on average yields, weather conditions, and soil on their farms.

Dr. Dong and Dr. Sundaramoorthi built the web program called *SimSoy* to help farmers utilize complex data and algorithms in an easy-to-use tool. It was created with soybeans as a test crop, but the technology can be used on any farm across a wide variety of crops.

The team leveraged big data from seed companies. This provided tens of thousands of data points, which was multiplied by the 182 seed varieties and the 1,000 simulations of weather predictions at each target site.

Using machine-learning simulations, researchers developed usable models that could be integrated into a web-based application. The team boiled down the tool to a 27-question form that includes location, soybean varieties, irrigation, soil types, acreage, and yields.

This computational model tailors recommendations to help farmers thrive by removing the guesswork during the planting season and improving crop yields based on variable planting conditions.

"We are intrigued by the opportunity to help farmers around the world, who often have limited access to and the knowledge of processing big data. This way, we can make the best use of what agricultural science offers."

– LINGXIU DONG

DATA &
INFORMATICS

TRANSDISCIPLINARY RESEARCH

The food system is a complex web of interactions among biology, technology, human behavior, economics, and policy. Transdisciplinary research requires the coordination of specialists from different fields of expertise, but scientists in one field, such as biology, are rarely trained to translate their findings in a way that can be readily used by researchers in another discipline, such as economics.

The "systems approach" is focused on discovering simplified strategies for integrating different academic fields in a way that will lead to solutions that are more useful for solving complex issues in production agriculture.

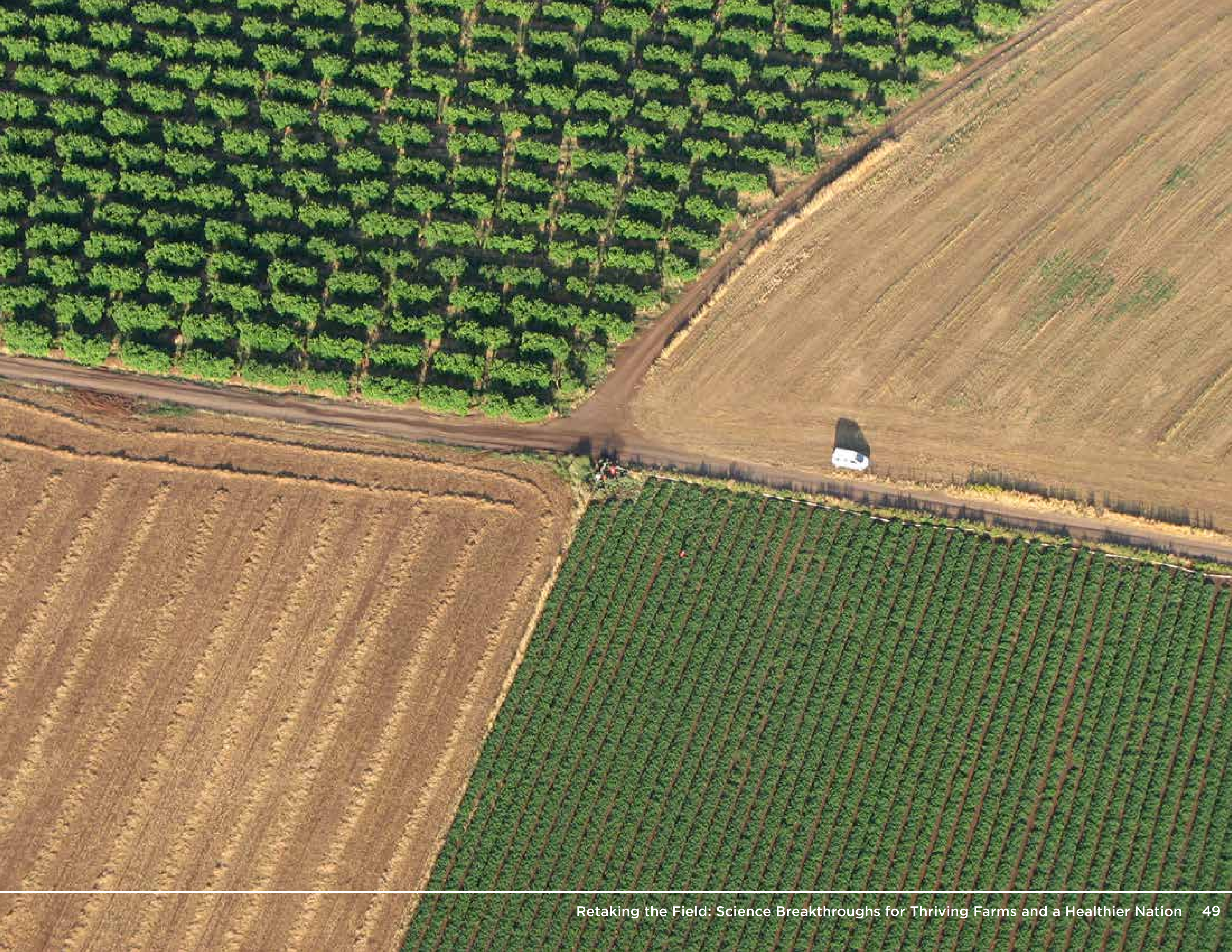
To advance our ability to sustainably feed the world's growing population, producers will need to combine science-based solutions that account for the realities of farming, such as shifting economic markets or limited access to technology. Transdisciplinary research will build the foundation for achieving creative solutions for our most pressing agricultural challenges.

NIFA-funded researchers are developing transdisciplinary teams to understand entire production systems that integrate multiple factors from scientific processes to human behaviors. For example, economists are weighing in on how water management practices will impact farm profitability, and nutritionists are evaluating how production practices improve the vitamin content of food.

By using transdisciplinary approaches, our scientists can better understand the complex factors impacting our food system without being confined by their individual area of expertise. Transdisciplinary collaborations will enable diverse teams to pool their knowledge and develop holistic solutions that increase the efficiency, resiliency, profitability, and sustainability of our food system.

How will transdisciplinary research create thriving farms and a healthier nation?

- Improve pollinator health through integrated pest management systems
- Increase adoption of science-based solutions that include environmental and economic perspectives
- Reduce greenhouse gas emission in animal production



BOOSTING BEES:

IMPROVING BEE HEALTH TO BENEFIT FARMERS

MICHIGAN STATE UNIVERSITY

PROBLEM
Declines in pollinators, such as bees, can impact fruit and berry production.

SOLUTION
Develop the most comprehensive and up-to-date picture of bee diversity, abundance, and health in Michigan to inform and implement recommendations.

RESEARCHERS
Rufus Isaacs, PhD, Michigan State University
Kelsey Graham, PhD, Michigan State University
Meghan Milbrath, PhD, Michigan State University
Doug Landis, PhD, Michigan State University
Zsofia Szendrei, PhD, Michigan State University

FUNDING
USDA NIFA Hatch
USDA NIFA Food Security Program
USDA NIFA Specialty Crops Research Initiative
MSU Project GREEEN

Michigan has an extraordinary 465 known species of bees. These species play different roles and are vital for pollinating apples, blueberries, cherries, cucumbers, squash, and many other crops. Unfortunately, habitat loss, bee parasites, and pesticides are making life difficult for bees, and populations of key species have declined over the past few decades.

Because pollinators are critical for the production of most berry crops, Dr. Isaacs and his transdisciplinary team investigate pollinator ecology and management, economic value, and benefits for agriculture. The group includes researchers experienced in honeybee management, wild bee ecology, and pest management. They also explore the interactions between landscape structure and insects, both natural enemies and pollinators, in Michigan farmland. This research is underway in fruit, field crops, and biofuel cropping systems.

The team studies the current state of pollinators to support Michigan fruit growers. Through the Great Lakes Pollinator Health Project, they sample pollinators across diverse landscapes, compare to current and past pollinator communities, and identify the importance of different stress on pollinators. The researchers also collaborate with berry, tree fruit, and vegetable growers to deliver Integrated Pest Management (IPM) programs for key insect pests, like Japanese beetle, grape berry moth, and spotted wing Drosophila.

Through their extension program, the team reaches out to growers with practical information. They apply this research by developing effective, economical, and environmentally sound pest management strategies to minimize the impact of pests in fruit production and to improve the contributions of wild and managed bees. This informs producers' decisions about insect management while improving farmers' productivity, profit, and environmental safety.

> *"My early training taught me that insects were fascinating but could be devastating. Helping farmers solve serious insect-related challenges made me realize how much goes into growing and delivering safe and profitable food. Those experiences laid the foundation for my research."*
>
> – RUFUS ISAACS

Photo credit: Kurt Stepnitz, Michigan State University


Photo credit: Kurt Stepnitz, Michigan State University

SUPPORTING SOIL:

IMPROVING THE WAY SCIENTISTS MEASURE AND COMMUNICATE THE VALUE OF SOIL

TEXAS A&M UNIVERSITY

PROBLEM

Some farmers are hesitant to adopt soil health-promoting practices such as no-tillage.

SOLUTION

Communicate the value of no-tillage systems and overcome barriers to help farmers improve soil management.

RESEARCHERS

Cristine Morgan, PhD, Texas A&M
Rich Woodward, PhD, Texas A&M
Alex McIntosh, PhD, Texas A&M
Srinivasulu Ale, PhD, Texas A&M
Farmers of the Brazos River Watershed

FUNDING

USDA NIFA AFRI
Texas A&M College of Agriculture and Life Sciences

Dr. Morgan and her team are helping farmers and the public understand the importance of soil health. No-till farming, or growing crops without disturbing the soil through tillage, is a soil health-promoting technique that allows farmers to grow crops and improve water quality and quantity at the same time. However, some farmers in Texas are not using these practices. Researchers want to understand why farmers aren't adopting no-till techniques so that they can learn how to better identify and communicate its benefits to producers.

With a transdisciplinary approach, researchers integrate soil science, hydrology, economics, sociology, and communications. They are developing better protocols for how to measure different soil processes and quantify these advantages to both producers and society. They are also searching for which soil health and social benefits resonate best with various stakeholders so that they know how to present their evidence in the most convincing way.

Farming is a constant problem-solving business. Farmers need to form and update their choices based on physical conditions, such as weather and soil moisture, as well as biological conditions, such as insects, bacteria, and fungi. Innovative farmers mentor and rely on each other's experiences and observations to help inform soil management decisions. By developing better ways of identifying, measuring, and communicating the benefits of soil health-promoting practices, the researchers are solving farmers' real-world problems with creative and practical solutions.

This project is enhancing dialogue among farmers, watershed stakeholders, scientists, and the public so that there is more adoption of management strategies that will fortify and secure our soil for future generations.

"I am a Native Texan who truly cares about the fate of our productive agricultural soils in Texas and the U.S. I thought I would go to law school, but once I took a soil science class, I was hooked on studying soils."

– **CRISTINE MORGAN**

Photo credit: Texas A&M University

DEFENDING DAIRY:

CONNECTING EXPERTISE TO REDUCE GREENHOUSE GAS EMISSIONS

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

PROBLEM
Dairy production is one of many contributors to greenhouse gas emissions.

SOLUTION
Develop strategies in the dairy production process to reduce emissions and maintain water and soil quality.

RESEARCHERS
Matthew Ruark, PhD, UW-Madison
Molly Jahn, PhD, UW-Madison
Michel Wattiaux, PhD, UW-Madison
Becky Larson, PhD, UW-Madison
Mark Powell, PhD, UW-Madison
Ken Genskow, PhD, UW-Madison
Mark Stephenson, PhD, UW-Madison
Doug Reinemann, PhD, UW-Madison

FUNDING
USDA NIFA AFRI

How can diverse viewpoints and expertise help reduce greenhouse gas (GHG) emissions?

Through multi- and trans-disciplinary research, this project connects animal scientists, agronomists, soil scientists, climatologists, engineers, systems scientists, economists, and others with a goal to understand each other's perspective. The team analyzes different parts of the dairy production system and identifies important gaps in the current science. This approach has led to impactful insights. For example, modeling and life cycle assessment efforts led to identification of best management practices to reduce GHG, while also improving water quality and farm profitability.

The dairy industry is committed to reducing GHGs associated with milk production. This includes examining areas such as cow management, manure management, and soil management to determine where the greatest opportunities are to reduce GHG as well as potential tradeoffs with other environmental losses.

The researchers learned that if farmers implemented best management practices worldwide to reduce GHG emissions, it would reduce impacts from climate change globally. Such practices include anaerobic digestion of manure (converting methane to less potent carbon dioxide), liquid-solid separation of manure, and using a manure storage cover. Producing milk more efficiently will lead to a reduction in GHG, a reduction in nitrogen and phosphorus runoff, and an increase in profitability.

The team also includes Penn State, Cornell University, University of Arkansas, University of Michigan, University of Maryland, University of Washington, USDA, and the Innovation Center for U.S. Dairy. Through USDA NIFA, producers and scientists are working together to sustainably produce food, protect the environment, and create win-win solutions.

"I study nutrient cycling and soil health across different agroecosystems. Maintaining and enhancing soil health is essential for the success of civilizations and to achieve food security on this planet. Research to improve soil is a long-term and vital investment."

– **MATT RUARK**

Photo credit: UW-Madison CALS

ABOUT *FedByScience*

FedByScience is a collective communications initiative to raise the visibility of public investment in food and agricultural research. Participating universities are joining together to tell impactful and inspiring stories about food and agricultural research. Its goal is to secure increases in congressional appropriations for capacity, extension, and competitive funding through the USDA's National Institute of Food and Agriculture (NIFA), as well as additional funding for state-level research. The SoAR Foundation coordinates *FedByScience*.

To join *FedByScience* or for more information, please contact Andrea Putman, Vice President, SoAR Foundation at: aputman@supportagresearch.org

The *Retaking the Field* series is available at: www.supportagresearch.org

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ABOUT SoAR

The Supporters of Agricultural Research (SoAR) Foundation is a non-profit, non-partisan coalition of partners that represent more than 6 million farming families, 100,000 scientists, universities, consumers, veterinarians, and others. Together, we are working to increase federal investments in agricultural research to produce the best possible agricultural science to help feed America and the world. SoAR advocates for full funding of the Agriculture and Food Research Initiative (AFRI), the USDA's flagship competitive grants program.

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