RETAKING THE FIELD

The Case for a Surge in Agricultural Research

SoAR FOUNDATION

ABOUT THIS REPORT

Spearheaded by the Supporters of Agricultural Research (SoAR) Foundation, this publication is a collaborative effort that celebrates the advances and explores the untapped potential of the agriculture and food sciences. The participating universities, and many others in the field, are committed to a future where these sciences have the researchers, resources, and stature to generate innovations that:

- Create jobs, increase profitability, and strengthen our economy
- Enhance the nutrition, affordability, and safety of food
- Safeguard public health and discover new treatments and cures
- Improve soil, air, and water quality
- Contribute to the security and stability of all nations

For more information on this project, its featured success stories, or agricultural research, contact Tim Fink at the SoAR Foundation (tfink@supportagresearch.org or 571-257-7625). A digital version of this material can be found at www.supportagresearch.org/retakingthefield.

PHOTO CREDITS, FRONT COVER (CLOCKWISE FROM TOP LEFT): USDA, DAVID CORNWELL, CAFNR, CHRISTINE BAEK

PUBLICATION STEERING COMMITTEE

Samara Sit
College of Agriculture and Life Sciences
CORNELL UNIVERSITY

Brian Meyer
College of Agriculture and Life Sciences
IOWA STATE UNIVERSITY

Dr. Chuck Rice
College of Agriculture
KANSAS STATE UNIVERSITY

Dr. Kate Stoll
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. Steve Lommel
College of Agriculture and Life Sciences
NORTH CAROLINA STATE UNIVERSITY

Dr. Jay Akridge
College of Agriculture
PURDUE UNIVERSITY

Ryan Adesnik
STANFORD UNIVERSITY

Dr. Walter Hill
College of Agriculture, Environment and Nutrition Sciences
TUSKEGEE UNIVERSITY

Dr. Michael Lairmore
School of Veterinary Medicine
UNIVERSITY OF CALIFORNIA, DAVIS

Dr. Jackie Burns
Institute of Food and Agricultural Sciences
UNIVERSITY OF FLORIDA

Dr. Robert Hauser
College of Agricultural, Consumer and Environmental Sciences
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Dr. Ronnie Green
UNIVERSITY OF NEBRASKA-LINCOLN

Caroline Arbanas
WASHINGTON UNIVERSITY IN ST. LOUIS

ASSERTING U.S. LEADERSHIP IN INNOVATION

The United States is the preeminent leader in agriculture. Today, food is more plentiful, affordable, and safer for families than ever before.

This success is rooted in a surge of federal research investment that began in the 1950s. During the "Green Revolution," scientific innovations like disease-resistant crops and new production methods were introduced to fields, enabling America's farmers to dramatically increase production.

The transformation saved an estimated 1 billion people from starvation and culminated in Iowa biologist Norman Borlaug accepting the Nobel Prize in 1970 on behalf of agricultural scientists everywhere.

Our nation's commitment to agricultural research, however, has since diminished. While funding for other fields grows, the U.S. Department of Agriculture's research budget has risen less than 1 percent since 2003. Growth in U.S. agricultural output has matched this trend. In contrast, China's production has skyrocketed—fueled by a tripling of government investment in the agricultural sciences that now outpaces that of the United States.

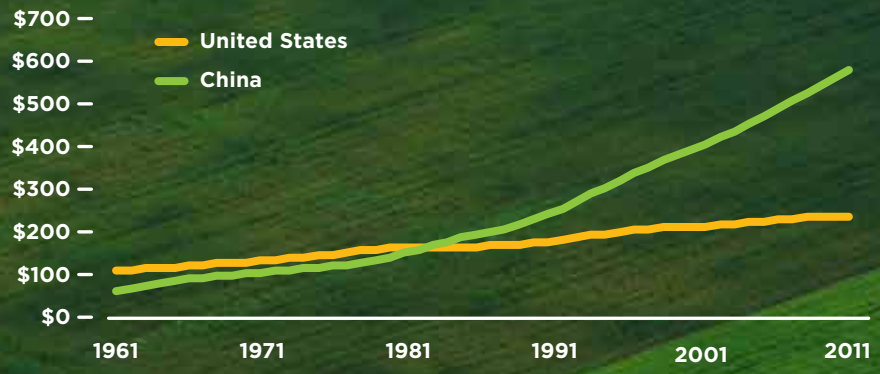
Farmers and policymakers are currently faced with a number of challenges: rising global competition, unprecedented demand, limited resources, volatile weather, and new threats to production. While the issues are daunting, the opportunities have never been greater. An increase in public agricultural research investment from Congress will provide outsized dividends—$20 for every $1 of federal funds invested, according to the USDA's Economic Research Service.

Researchers have at their disposal new tools, techniques, and knowledge that were unimaginable a few decades ago. Breakthroughs in genomics and nanotechnology are improving food safety and human health. Scientists are discovering ways to increase production while minimizing the impact on the land and water. And the barrier between the lab and the field is crumbling as data flows directly from researchers into the hands of farmers.

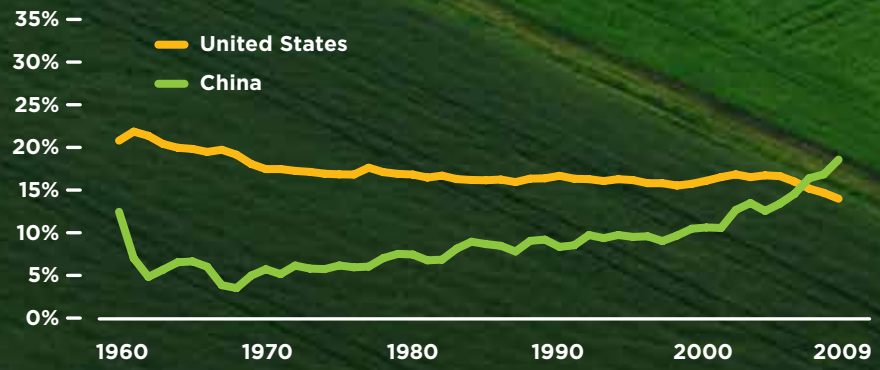
This report makes the case for a new surge in federally funded agricultural research. It illustrates how this increase would benefit the lives of all Americans, regardless of where they live. It shows how researchers across the country stand ready to retake the field.

TOTAL NATIONAL GROSS AGRICULTURAL PRODUCTION[1]

Valued at constant, global-average prices from 2004–2006, expressed in 2005 international dollars and measured in millions



COUNTRIES AS SHARE OF TOTAL GLOBAL PUBLIC AGRICULTURAL RESEARCH AND DEVELOPMENT[2]



1 http://www.ers.usda.gov/dataFiles/Internationalproductivity/AgTFPindividualcountries.xlsx
2 *Agricultural Innovation: The United States in a Changing Global Reality.* Pardey, Beddow

"The tide of the battle against hunger has changed for the better... But tides have a way of flowing and then ebbing again."

– DR. NORMAN BORLAUG, 1970 NOBEL PRIZE ACCEPTANCE SPEECH

MARC WIELAND

THE STORY OF U.S. AGRICULTURAL RESEARCH HAS ALWAYS BEEN ONE OF SUCCESS

Even in today's lean times, when federal science funding has been increasingly constrained, researchers nationwide are cobbling together support to solve the vexing problems. These challenges include fast-moving animal pandemics, water conservation, crop productivity, and even the age-old struggle to get kids to eat right.

This report explores 13 stories of success that are unfolding at a few of our nation's leading research institutions. Since food and agriculture research spans many disciplines, we cannot represent its full breadth within this short report. Instead, we present examples within four broad categories:

PRODUCTION

HUMAN HEALTH

FOOD SAFETY

KNOWLEDGE TRANSFER

Some of these stories tackle immediate crises, while others address troublesome situations in the near future. All of them show how the power of science-driven innovation can improve lives.

PRODUCTION

IOWA STATE UNIVERSITY
Protecting Soil and Water with Strips of Native Prairie 6

UNIVERSITY OF FLORIDA
Creating an Early Detection System for Florida's Diversifying Agriculture Sector 7

KANSAS STATE UNIVERSITY
Responding to an Emerging Disease 8

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Comparing the Impacts of Future Air Pollution and Rising Temperatures on Key Crops 9

HUMAN HEALTH

STANFORD UNIVERSITY
Harnessing Plants to Produce Safer, Less Expensive Drugs 12

CORNELL UNIVERSITY
Fighting Childhood Obesity with Better Marketing 13

WASHINGTON UNIVERSITY IN ST. LOUIS
Targeting Gut Microbes to Fight Malnutrition 14

FOOD SAFETY

TUSKEGEE UNIVERSITY
Developing an Onsite Solution for Safer Food 18

NORTH CAROLINA STATE UNIVERSITY
Tracking and Minimizing Foodborne Bacteria with Cutting-Edge Technology 19

UNIVERSITY OF CALIFORNIA, DAVIS
Creating a Fingerprint Database for Foodborne Pathogens 20

KNOWLEDGE TRANSFER

UNIVERSITY OF NEBRASKA–LINCOLN
Helping Farmers Save Enough Water to Double Nebraska's Largest Lake 24

PURDUE UNIVERSITY
Mapping the Potential of Soil 25

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Transferring Science and Translating Policy for Farmers 26

PRODUCTION

Protecting a Pillar of Our Economy for a Growing World

Agriculture and its related industries were responsible for nearly 1 in 10 jobs in 2014 and contributed $835 billion to the U.S. gross domestic product.[3] The hard work of producers and researchers has enabled American families to spend less on—and have better access to—food than any other country.

Yet this trend may be in danger as the industry faces a host of new production challenges. The year 2015 was one of record-setting extremes. California's historic drought continued, threatening crops in a state that produces 13 percent of our nation's farm commodities.[4] New pests and diseases are also emerging. A 2015 avian influenza outbreak led to billions of dollars in damages and the culling of more than 48 million chickens, ducks, and turkeys in 15 states.[5]

Similar problems are being experienced throughout the world. With population projected to rise to 9 billion by 2050,[6] 2 billion more than today, policy experts wonder how food production can sustainably keep pace. The Arab Spring reminded us of the importance of "food security." The lack of food or a spike in prices can trigger strife in unstable countries, as well as nations long thought to be secure. Egypt's 2011 revolution, for example, started as protests over the price of bread.

These challenges can be solved, however. New technologies are enabling researchers to understand complex webs of variables and combat pests and diseases in novel ways. Researchers are also discovering new methods and technologies to increase production while conserving soil and water.

Innovation driven by science is key to sustaining the agricultural sector's vitality, conserving natural resources, and ensuring that all people have adequate and nutritious food. These critical goals can only be achieved through more research.


CAFNR

3 http://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy.aspx
4 https://www.cdfa.ca.gov/statistics/
5 http://www.reuters.com/article/health-birdflu-usa-rebuilding-idUSL5N10P01H20150826
6 http://www.un.org/en/development/desa/news/population/2015-report.html

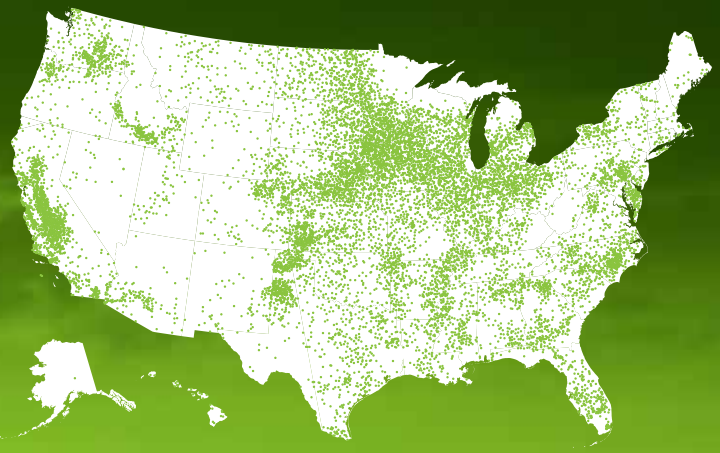
FOOD PRICES ARE RISING FASTER THAN THE CONSUMER PRICE INDEX[7]

Percent change in food prices compared to overall inflation, 2011-2015

EVERY STATE IN THE U.S. PRODUCES AGRICULTURAL COMMODITIES[8]

Market value of agricultural products sold: 2012

1 dot = $20 million



7 USDA, Economic Research Service using data from the U.S. Bureau of Labor Statistics
8 USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, 2012 Census of Agriculture

PROTECTING SOIL AND WATER WITH STRIPS OF NATIVE PRAIRIE

PRODUCTION

IOWA STATE UNIVERSITY

PROBLEM

Runoff removes soil and nutrients from row crop farm fields and poses water quality problems for those living downstream.

SOLUTION

Converting 10 percent of a crop field to strips of native prairie reduces water runoff by 44 percent, soil loss by 95 percent, nitrogen in runoff by 84 percent, and phosphorus in runoff by 90 percent.

RESEARCHERS

Lisa Schulte Moore, PhD;
Matthew Helmers, PhD; and others

FUNDING

Iowa State University
Iowa State University Leopold Center for Sustainable Agriculture
USDA Agriculture and Food Research Initiative
USDA Hatch and McIntire-Stennis
USDA Farm Service Agency
USDA Forest Service, and others

Farmers today manage their fields for many different results. They work to increase yields and earn a profit while protecting the land's soil and water resources. Rain, especially torrential rain, is a major challenge since it can wash away fertilizer and susceptible soil. This problem is called runoff.

Dr. Lisa Schulte Moore and Dr. Matthew Helmers lead an interdisciplinary team of scientists who have found an innovative way to minimize runoff, keeping water clean without sacrificing production. The research team is experimenting with strategically planting strips of native prairie within corn and soybean fields.

"Farmers respond to data. It's our job to provide them with the best possible information for managing their fields to meet a variety of goals." – LISA SCHULTE MOORE, PHD

They learned that prairie plants' deep, interlocking roots and stiff, upright stems provide the perfect architecture for preventing runoff. By strategically interspersing these strips on an average of 10 percent of a field, they are able to drastically reduce water, soil, and nutrient loss without altering per acre-yield. The team also determined that the practice does not cause fields to become overrun with weeds.

Their next step is to work with additional farmers and partners in Iowa and beyond to implement the practice and monitor results.

CREATING AN EARLY DETECTION SYSTEM FOR FLORIDA'S DIVERSIFYING AGRICULTURE SECTOR

PRODUCTION

UF UNIVERSITY of FLORIDA

PROBLEM
As Florida agriculture expands and farmers produce a wider variety of commodities, their fields are threatened by a greater number of pathogens.

SOLUTION
The early detection system at the University of Florida identifies plant diseases and other problems outside the state that now threaten Florida crops.

RESEARCHER
Carrie Lapaire Harmon, PhD

FUNDING
USDA Agriculture and Food Research Initiative

In Florida, agriculture is diversifying. Farmers in the state produce the most oranges, grapefruits, fresh market tomatoes, and several other commodities.[9] They are constantly expanding the variety of crops they plant, but this exposes Florida to an even greater variety of plant diseases.

Dr. Carrie Lapaire Harmon's lab, Florida's Plant Diagnostic Center, serves as the state's early detection system. Her lab is equipped to quickly test and diagnose numerous plant diseases, including those never before seen in the state, to prevent devastating outbreaks.

Her team recently investigated the pathogen plaguing Loropetalum, a popular garden shrub, and discovered key differences between it and olive knot, another pathogen that has yet to appear in Florida's olive groves. The analysis eased the anxiety of farmers looking to increase their olive production.

"Plant pathogens are like tourists. They come to Florida and say, hmm, I'd like to stay here."

– CARRIE LAPAIRE HARMON, PHD

In 2016, the Center examined potato samples thought to be afflicted by the Zebra Chip bacteria. Instead, Dr. Lapaire Harmon's team found that the plants suffered from a less virulent pathogen and also needed better care and management. The diagnosis saved the farmer from having to eliminate his entire crop and also averted a statewide alarm.

Detecting pathogens and addressing them before they escalate is the Center's goal, and success comes when crises never happen.

9 http://www.freshfromflorida.com/Divisions-Offices/Marketing-and-Development/Education/For-Researchers/Florida-Agriculture-Overview-and-Statistics

RESPONDING TO AN EMERGING DISEASE

PRODUCTION

KANSAS STATE UNIVERSITY

PROBLEM
The PED virus killed around 5.2 million piglets in the first year after it emerged in the U.S. in 2013.[10] Scientists did not know how it was transmitted or how to stop it.

SOLUTION
Researchers confirmed feed as a means of transmission and discovered that heating the feed to at least 130°F and other feed processing steps prevents the virus' spread.

RESEARCHER
Jason Woodworth, PhD

FUNDING
USDA Multistate Research Fund
National Pork Board
Kansas State University

Farmers in Asia and Europe have struggled with Porcine Epidemic Diarrhea virus (PEDv) outbreaks for decades, but the virus did not reach the U.S. until spring of 2013. In the fall of that year, it killed 1.4 million piglets[11] and health authorities had to move quickly.

Researchers at Kansas State University sprang into action. Dr. Jason Woodworth and his team first confirmed pig feed as a path of transmission. This was novel for viruses. The team then determined the minimum amount of virus in the feed that would lead to infection.

"In university research, we're looking for solutions that benefit the whole industry. We're trying to find ways to improve nutrition, production, and overall profitability."

– JASON WOODWORTH, PHD

The researchers scrutinized the feed production process and discovered that forming feed into pellets using temperatures of at least 130°F killed the virus, rendering the feed safe. Other solutions, such as treating feed with medium chain fatty acids, were also discovered to prevent infection. As a result, new feed processing steps for maintaining virus-free feed have been implemented nationally.

The team at Kansas State played a critical role in containing the outbreak. The cumulative incidence of PEDv infections dropped from 56 percent in 2013-4 to 6 percent in 2015-16.[12]

10 http://www.ncbi.nlm.nih.gov/pubmed/26641031
11 http://www.agri-pulse.com/Deadly-pig-disease-trims-supplies-drives-pork-prices-higher-112913.asp
12 http://www.cihedging.com/assets/cih/hogmargin/SHMP.pdf

COMPARING THE IMPACTS OF FUTURE AIR POLLUTION AND RISING TEMPERATURES ON KEY CROPS

PRODUCTION

Massachusetts Institute of Technology

PROBLEM

Air pollution and climate change are both potential risks to agriculture. However, their impacts on different crops and in different regions is not well understood.

SOLUTION

As the U.S. climate shifts, conditions will favor wheat over corn. However, the success of wheat and other plants will depend on limiting air pollution.

RESEARCHER

Colette L. Heald, PhD

FUNDING

The Croucher Foundation
National Park Service
National Science Foundation

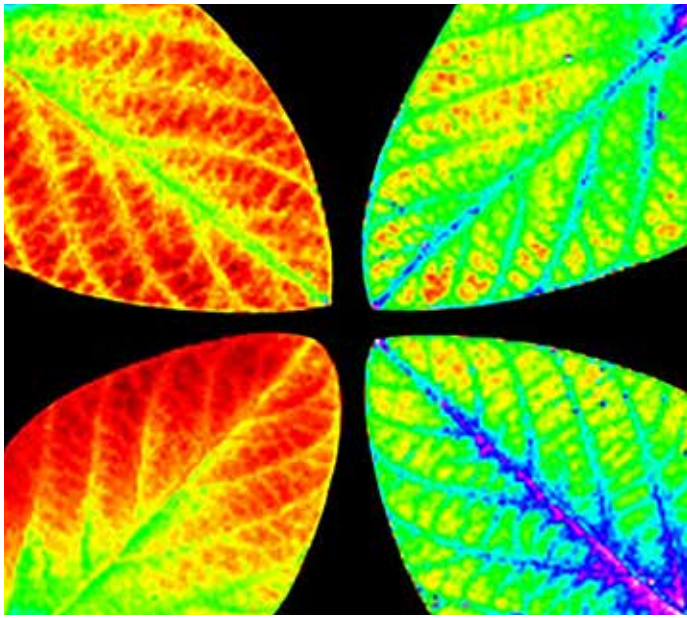
Ground level ozone, not to be confused with the ozone layer in the stratosphere, is considered one of the more dangerous components of air pollution. While its impacts on human health are well known, its effects on agriculture are not as well studied.

Ozone is toxic to many plant species and tends to increase with temperature. Using supercomputers at the National Science Foundation's facility in Wyoming, Dr. Colette Heald and her team integrated models for ozone pollution with the anticipated impacts of climate change on global crop yields.

"Many are familiar with the link between temperature and crop production. But most don't realize how damaging ozone can also be for plants." – COLETTE L. HEALD, PHD

Projecting out to 2050, they discovered that while wheat is less sensitive to the shifting weather patterns in the U.S. than corn, wheat is more sensitive to ozone. Dr. Heald's work suggests that adaptation efforts replacing corn with wheat should be coupled with initiatives limiting ozone pollution to maximize production. While the team estimated that the combination of air pollution and the changing climate would reduce global food production 2050 by up to 15 percent, cleaning up ozone emissions would reduce this to 11 percent.

Dr. Heald's team will tackle particulate pollution next, creating another layer of understanding in the effort to improve agricultural planning over the coming decades.



Photosynthetic activity of soybeans is hampered by ozone pollution. (From Kim, M.S., McMurtrey, J.E., Mulchi, C.L., Daughtry, C.S.T., Chappelle, E.W., and Chen, Y.R. Steady-state multispectral fluorescence imaging system for plant leaves. *Applied Optics*, 40:157-166. 2001)

HUMAN HEALTH

Safeguarding the Well-being of People Everywhere

It is hard to underestimate the impacts of the food and agriculture sciences on human health. Many of our pharmaceuticals are made from plants, and efforts to improve the well-being of animals have unearthed new cures and insights into human diseases.

Agricultural research is also used to improve nutrition. In the U.S., the rate of childhood obesity has doubled over the past 30 years. Today, more than one-third of children and adolescents are overweight. Adults are also struggling to stay healthy with chronic diseases like high blood pressure and diabetes on the rise. An estimated 85 percent of Americans do not meet the U.S. Food and Drug Administration (FDA) recommended levels for the most important vitamins and minerals.

Internationally, the challenges are a bit different. Many people still live in places where it is difficult to get enough calories, let alone a balanced diet with the nutrients needed to stay healthy. At the same time, obesity rates are on the rise and most of the world lives in countries where obesity poses more challenges than hunger.[13]

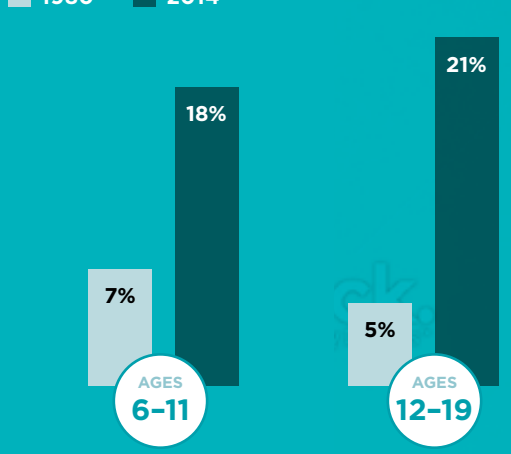
There is cause for optimism. At home, researchers are finding simple yet effective ways to get kids to eat better. Abroad, American researchers are exploring ways to get valuable nutrients to children in the most food-insecure of environments. Scientists are even finding ways to engineer plants to make lifesaving drugs more accessible.

Americans cannot become healthier if what they eat does not become healthier. This starts with putting better food on the plate. Scientists are meeting this challenge so that all of us can have our cake and eat it too.

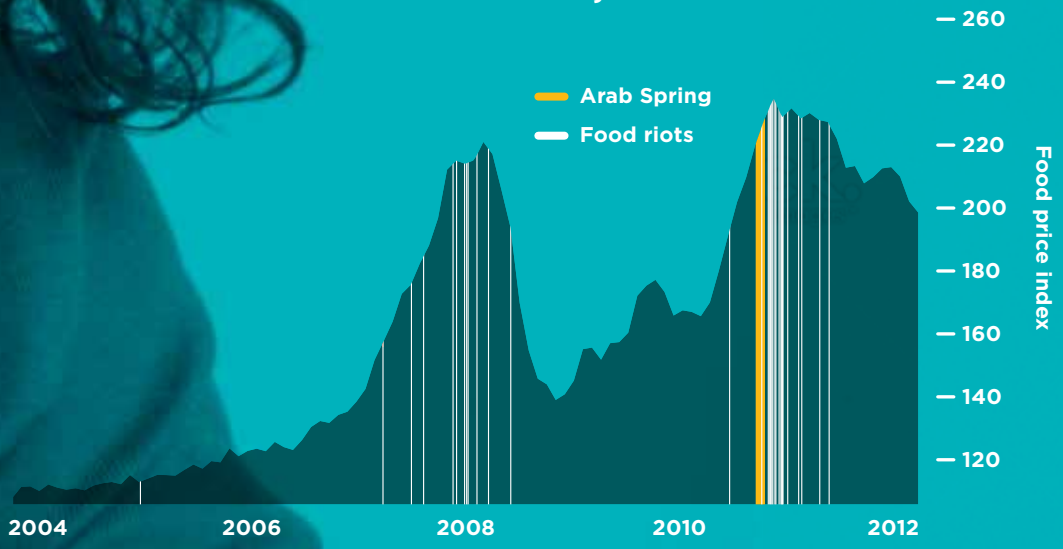
13 http://www.who.int/mediacentre/factsheets/fs311/en/

OBESITY IS ON THE RISE[14]

Percentage of obese children in the United States



CORRELATION OF FOOD PRICE INDEX TO GLOBAL SOCIAL UNREST, 2004 TO 2012[15]



14 http://onlinelibrary.wiley.com/doi/10.1002/oby.21497/epdf
15 Lagi, Bertand, Bar-Yam 2011

HARNESSING PLANTS TO PRODUCE SAFER, LESS EXPENSIVE DRUGS

HUMAN HEALTH

Stanford

PROBLEM
Processing plants to produce lifesaving drugs like etoposide, a chemotherapy agent, is expensive, time-consuming, and labor intensive.

SOLUTION
A new technique uses a relative of the tobacco plant to produce a cancer drug. The process requires fewer resources and can be used to produce other drugs.

RESEARCHER
Elizabeth Sattely, PhD

FUNDING
National Institutes of Health

When we think of the value of plants, we often visualize sources of food, not pharmaceuticals. However, many of the world's essential medicines are derived from plants in processes that are too often inefficient, unreliable, and environmentally destructive.

Dr. Elizabeth Sattely and her team are exploring how plants can be re-engineered to serve as miniature chemical production facilities to produce a wide array of biological agents. Their target is *Nicotiana benthamiana*, an Australian relative of the tobacco plant whose "flexible" chemistry has been harnessed in a number of laboratory applications. At Stanford, a *Nicotiana* variety is being used to produce the chemotherapy agent Etoposide, a drug used to treat many different kinds of cancers.

"This work not only has the potential to make lifesaving drugs more accessible, but also safer and more reliable." – ELIZABETH SATTELY, PHD

The current process for producing Etoposide involves using large quantities of the Himalayan Mayapple, an endangered plant that has been overharvested since the drug's discovery. Dr. Sattely's process is faster and can also make it easier for researchers to make analogs of the drug that could have reduced side effects and improved effectiveness.

FIGHTING CHILDHOOD OBESITY WITH BETTER MARKETING

HUMAN HEALTH

Cornell University

PROBLEM
Childhood obesity has more than doubled in children and quadrupled in adolescents in the past 30 years.[16]

SOLUTION
Deploying marketing strategies used to generate impulse purchases can encourage kids to eat better at school while cutting cost and waste.

RESEARCHER
David Just, PhD

FUNDING
USDA Agriculture and Food Research Initiative
USDA Economic Research Service

Marketers have mastered the art of generating impulse purchases at grocery stores. Customers waiting in line find tantalizing candy and other treats within their reach.

Dr. David Just is applying these principles to school cafeteria lines. To entice children to eat more fruit, produce is removed from the "servings" area and placed by the cash register. While waiting in line, students were more likely to grab an apple. This simple approach more than doubles their fruit consumption.

"Behavioral science doesn't just work for unhealthy foods; the same tools can be used to get kids to make healthy choices."

– DAVID JUST, PHD

In another example, researchers set white milk in front of chocolate milk. When kids have to reach three more inches for chocolate, an additional one-quarter of kids take the lower-calorie option. Even rebranding mundane items can make a big difference. When foods become "X-ray Vision Carrots" and "The Big Bad Bean Burrito," school vegetable sales nearly double.[17]

These approaches are more effective than having cafeteria workers place healthy foods on the kids' trays, or other methods where kids play a passive role. Making it easier and more fun for kids to make the right choice is key to getting them to eat better.

16 http://www.cdc.gov/healthyschools/obesity/facts.htm
17 http://foodpsychology.cornell.edu/discoveries/whats-name

TARGETING GUT MICROBES TO FIGHT MALNUTRITION

HUMAN HEALTH

Washington University in St. Louis

PROBLEM
Three million children die annually from malnutrition. Nutritious foods reduce deaths but may not help the children's stunted growth and related problems.

SOLUTION
Developing therapeutic foods that target gut microbial communities can promote healthy growth, address developmental delays, and prevent disease.

RESEARCHER
Jeffrey I. Gordon, MD

FUNDING
National Institutes of Health
Bill & Melinda Gates Foundation

Nutrient-dense therapeutic foods have reduced deaths from childhood malnutrition but do little to improve long-term problems linked to the condition, including stunted growth, impaired brain development, and weakened immune systems.

Research from Dr. Jeffrey I. Gordon's team indicates that malnourished children have gut microbial communities (microbiota) that are "immature." The group transplanted gut communities from malnourished African children into young mice that lacked gut microbes of their own. The immature microbiota produced poor growth and other characteristics of malnutrition in the animals. Through additional studies, Dr. Gordon has identified gut bacteria that direct healthy growth.

"Our work provides a microbial view of human development and suggests potential new therapies for malnutrition that target gut microbes to promote healthy growth."

– JEFFREY I. GORDON, MD

For example, his team and colleagues at the University of California-Davis have identified a component of breast milk that works through gut microbiota to promote growth. This type of milk sugar is reduced in mothers of malnourished infants. Giving this milk sugar to mice or piglets whose guts have been colonized with a malnourished child's microbiota improved skeletal, muscular, and brain development.

Dr. Gordon is using these insights to develop therapeutic foods designed to repair gut microbiota problems and produce better outcomes in the worldwide fight against childhood malnutrition.

DWIGHT SIPLER

FOOD SAFETY

Keeping Pathogens Off the Menu

An important role for agricultural research is not just ensuring that there is enough food, but that the food we have is safe. A few years ago, efforts to prevent foodborne illnesses resembled those from the 1960s. As food was produced, a sample of what was shipped for retail sale was tested at an offsite lab. If the test revealed a problem, the product was recalled. Because of the complexities of this system, contaminated food too often fell through the cracks.

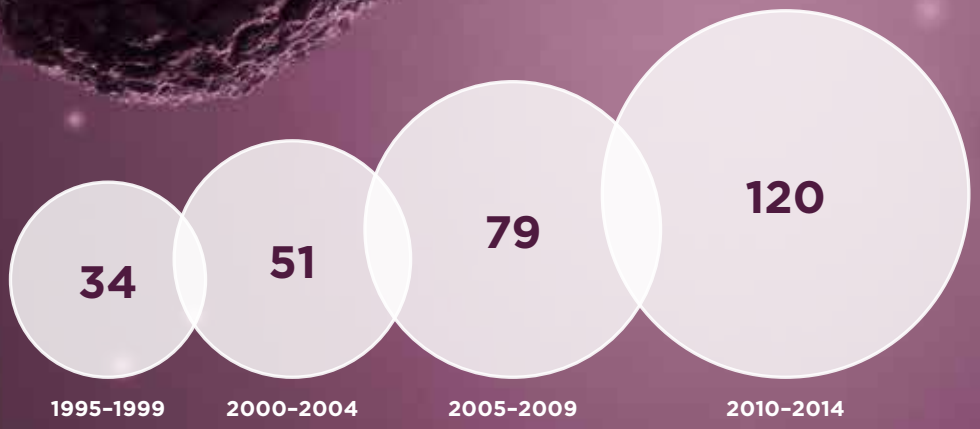
If a foodborne outbreak occurred, experts resorted to old-fashioned detective work—interviewing patients to see what they had eaten and where they had eaten it—to trace the culprit food item. The process was time-consuming and the longer it took, the greater the number of people who became ill.

Complicating matters is the fact that our food system is now more global than ever before. The distance it travels, the many ways it is processed, and the numerous steps along the supply chain, provide even more opportunities for the introduction of pathogens. But efforts to keep the food safe are finally entering the digital age.

Today, we are poised to make immense strides in protecting our food. Scientific innovations are revolutionizing every aspect of food safety—including the accuracy of tests, how long they take, where they can be performed, and how threats can be removed once discovered. In the event that a pathogen finds its way to consumers, new technologies are enabling rapid identification of the source. Importantly, food producers are embracing new techniques that streamline their production and transportation processes.

Yet even as the industry transforms, enough food staples have been contaminated by bacteria since 2010 to ruin every imaginable meal—even dessert. A steady diet of scientific research will always be required to keep our food from spoiling and free of diseases.

MORE MULTISTATE OUTBREAKS ARE BEING FOUND[18]



SINCE 2010, FOOD POISONING HAS APPEARED IN TOO MANY MEALS

Year	Contaminated food
2010	Eggs Celery
2011	Cantaloupes Ground turkey
2012	Peanut butter
2013	Lettuce Cilantro and salad mix Chicken salad
2014	Caramel apples
2015	Ice cream Cucumbers
2016	Cheese Alfalfa sprouts Frozen vegetables

18 CDC National Outbreak Reporting System, 1995-2014.

DEVELOPING AN ONSITE SOLUTION FOR SAFER FOOD

FOOD SAFETY

TUSKEGEE UNIVERSITY

PROBLEM

Current techniques for detecting foodborne pathogens take too long, cannot simultaneously scan for a wide range of pathogens, and require specialized facilities.

SOLUTION

A new portable detection method can identify a wide array of foodborne pathogens, including *Salmonella*, in less than 10 minutes. Nanotechnology can then remove the pathogens.

RESEARCHERS

Woubit Abdela, PhD;
Temesgen Samuel, PhD; and
Teshome Yehualaeshet, PhD

FUNDING

Department of Homeland Security
National Center for Food Protection and Defense
USDA Agriculture and Food Research Initiative

Many food production facilities lack the equipment needed to detect pathogen contamination. Samples are mostly tested offsite while finished products are shipped for sale, before the results become available. Dr. Woubit Abdela, Dr. Temesgen Samuel, and Dr. Teshome Yehualaeshet at Tuskegee University have tinkered with a 30-year-old genetics tool to invent a fast and portable detection method.

The team started by programming a PCR (Polymerase Chain Reaction) Microplate Array to detect unique genomic regions of 12 different foodborne and food-threat pathogens. They then adjusted this technology to identify 25 common *Salmonella* strains from a variety of foods. This work was then adapted for onsite monitoring and detection using a hand-held lab device developed for DNA detection.

"For the typical scientist, the fun is what happens in the lab. But we can't stop there. We need to ensure new technology gets developed and disseminated."

– TEMESGEN SAMUEL, PHD

But the team did not stop at detection. They figured out how to modify gold and magnetic nanoparticles to bind with salmonella DNA or specific receptors. This system sandwiches the bacteria between the two particles to enable the removal of *Salmonella* from the food using a magnetic device.

The researchers have secured patents for these innovations in hopes of licensing the technologies to food producers and government agencies in order to prevent foodborne outbreaks.

TRACKING AND MINIMIZING FOODBORNE BACTERIA WITH CUTTING-EDGE TECHNOLOGY

FOOD SAFETY

NC STATE UNIVERSITY

PROBLEM
According to the CDC, around 48 million Americans are infected by foodborne pathogens every year with 128,000 hospitalized and 3,000 killed.

SOLUTION
Using the CRISPR technology—the latest in genetic science—strains of *E. coli* can be traced to their source and potentially eradicated without harming beneficial bacteria.

RESEARCHER
Rodolphe Barrangou, PhD

FUNDING
U.S. Centers for Disease Control
U.S. Food and Drug Administration
North Carolina Biotechnology Center, and others

Investigators currently approach the challenges of containing an outbreak of foodborne illness from an epidemiological standpoint by attempting to link patients to a likely source of contamination. Dr. Rodolphe Barrangou is using a new technology known as CRISPR, which dramatically speeds up the editing of bacterial genetics, to examine the pathogen's DNA and determine its origin and the route it took in triggering an outbreak.

Dr. Barrangou, who won two prestigious awards in 2016 for his role in developing CRISPR while working in private industry, is also using the process to potentially cure patients suffering from foodborne illness. He is programming phages—viruses that attack bacteria—to eliminate virulent strains of *E. coli*. This process could even be used against antibiotic-resistant strains, a rapidly mounting concern within the health community.

"Universities play a vital role in serving the world. As a professor, I can share more about my CRISPR research and contribute to a broader range of applications and sciences."

– RODOLPHE BARRANGOU, PHD

His process may prove better for patients than traditional antibiotics. Most antibiotics do not discriminate between good and bad bacteria. When they are taken to treat *E. coli*, they also kill microorganisms in the digestive tract that help people synthesize key nutrients. Barrangou's CRISPR technique would only target the *E. coli*, leaving the patient's gut flora intact and accelerating recovery.

CREATING A FINGERPRINT DATABASE FOR FOODBORNE PATHOGENS

FOOD SAFETY

UC DAVIS
UNIVERSITY OF CALIFORNIA

PROBLEM
Efforts to identify and trace foodborne pathogens have traditionally relied on slow, 1940s technology to detect an outbreak or food contamination.

SOLUTION
Using DNA sequencing, a library of known pathogens is being built to rapidly determine the exact strain and source of outbreaks and food contamination for recalls.

RESEARCHER
Bart C. Weimer, PhD

FUNDING
Mars, Inc.
IBM
Department of Health and Human Services
Department of Defense
Agilent Technologies
Pacific Biosciences
Kapa Biosystems, and additional industry partners

The genome of any organism can be used as a bar code, allowing quick identification of a particular strain. This is exceptionally important in food safety and public health efforts. If contamination is found on a food product—or, worse, someone contracts a bacterial infection—investigators need to know the pathogen and the potential sources of contamination along the food supply chain. The old way of doing things—growing bacteria—takes too long and cannot contain fast-moving outbreaks.

"When foodborne illness outbreaks occur, the regulators and industry need to figure out traceability and accountability. Genomics has become so good that these attribution questions are now gone." – BART C. WEIMER, PHD

Dr. Bart Weimer and his team at UC Davis, School of Veterinary Medicine, are creating a massive database of genome signatures—collecting the "fingerprints" of 65,000 strains of *Salmonella* so far. The initiative, called the 100K Pathogen Genome Project, began as an innovative public-private-academic partnership. They have also partnered with international food safety agencies and universities to expand the database for global trade and traceability.

Their work enables public health agencies and the food industry to trace outbreaks to their source by comparing the genome of the pathogen to their database, which includes information on previously detected strains as well as their exact locations. The new approach swiftly provides conclusive evidence of the contamination source by processing millions of pieces of evidence.

DECLAN REX

KNOWLEDGE TRANSFER

Reinventing and Digitizing the Farmer's Almanac

In the 19th century, many farmers relied on *The Farmer's Almanac* for every kind of information under the sun—including weather forecasts for the entire year. The accuracy of the information and predictions were usually not helpful, and the books were not always easy to acquire.

Today, farmers benefit from vastly improved information and predictions about what to grow, when to plant, and what conditions they will face along the way. Everything from weather to pestilence can be predicted with much greater certainty.

Farmers also benefit from information systems that provide this data in easier and more accessible ways. For many farmers, the tractor has become the office place as desktop computers have given way to smart phones and tablets. Information can be updated in real time, not daily, weekly, or annually. The information can also be customized to the precision of inches within a farm field.

The Farmer's Almanac is still in print today, approaching its 200th year. Yet it has become a metaphor for the traditional ways of conducting business. As government policies, growing seasons, and pests and diseases continue to evolve, the almanac can stay on the bookshelf. Innovation has changed everything on the farm, even the way farm advancements and new technologies are disseminated.

HELPING FARMERS SAVE ENOUGH WATER TO DOUBLE NEBRASKA'S LARGEST LAKE

KNOWLEDGE TRANSFER

University of Nebraska Lincoln

PROBLEM

The Ogallala aquifer, which has lost roughly a third of its original reserves to irrigation, supports about 20 percent of U.S. cattle, corn, cotton, and wheat production.[19]

SOLUTION

After more than 10 years of working with research-based practices, Nebraska farmers saved 1.8 million acre-feet of water—enough to refill the state's largest lake.

RESEARCHER

Suat Irmak, PhD

FUNDING

USDA Natural Resources Conservation Service and other sources

When Dr. Suat Irmak joined the faculty at the University of Nebraska-Lincoln in 2003, he conducted a comprehensive needs assessment to determine what issues he should tackle. The depletion of the Ogallala aquifer, a vast underground reservoir that feeds most of Nebraska's farms, was at the top of the list.

He researched and identified advanced technologies to improve farm productivity while conserving water and energy. These technologies have been applied in over 1.7 million acres of irrigated croplands across Nebraska.

Dr. Irmak has been taking his team's research to a network of farmers created through direct outreach. In 2005, the Nebraska Agricultural Water Management Network started with just 15 farmers. Today, it is up to 1,400. Through this network, farmers have embraced conservation principles and technologies, reducing irrigation by more than two inches per acre each growing season.

"We work with farmers to learn about real-world issues. Sharing our results for adoption is as important as the research itself."

– SUAT IRMAK, PHD

Nebraska's use of irrigation management technology has also increased. The state now ranks second nationally in deploying these innovations. The network also increased the scientific literacy of Nebraska's agricultural community, helping them understand, for example, how changes in climate variables impact their fields.

With no end to water worries in sight, Dr. Irmak will continue to discover and propagate new ways to save.

19 http://www.bloomberg.com/news/articles/2015-07-02/great-plains-water-crisis-aquifer-s-depletion-threatens-farmland

MAPPING THE POTENTIAL OF SOIL

KNOWLEDGE TRANSFER

PURDUE UNIVERSITY

PROBLEM
Soil quality is a crucial component for growing any crop, yet can vary dramatically by location, even on the same farm.

SOLUTION
Functional soil maps with organic carbon levels, clay concentration, water table locations, and other details, help farmers maximize production and efficiencies.

RESEARCHER
Phillip Owens, PhD

FUNDING
Purdue University
USDA
National Science Foundation

In the past, agriculture mapping technology focused on appearances and taxonomy. Satellite and aerial data showed topographical features and the color of the topsoil hinted at the composition of what lay underneath. But appearances only run skin deep.

Purdue scientists have developed algorithms that account for how soil in specific locations interact with landscape features like streams and water catchments. These algorithms provide farmers with differences in soils and the minimum number of places required to properly sample field soil. Working from these patterns and soil samples, Dr. Phillip Owens and his team then produce maps with three-dimensional modelling.

"Farmers are eager for information at a scale they can use. Our mapping technology marks an important step in taking some of the guesswork out of managing their soil."

– PHILLIP OWENS, PHD

The maps can be powerful decision-making tools, helping farmers determine which crops to plant and how to fine-tune fertilizer applications and irrigation. This increases production while limiting inputs. To make this tool more accessible, Dr. Owens and Purdue have created a mobile app that lets farmers access the maps from the tractor. In addition, they have licensed the technology to a private company to ensure broader distribution.

The maps are also being created in developing countries where less is known about the soil and the margin between successful harvests and starvation can be razor thin.

TRANSFERRING SCIENCE AND TRANSLATING POLICY FOR FARMERS

KNOWLEDGE TRANSFER

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PROBLEM
Farmers in the "Corn Belt"—the central and northern part of the mid-western U.S.—need to access and understand current science and complex policy to take advantage of new opportunities.

SOLUTION
"Farmdoc" is an online tool that presents applied research and commodity analyses along with interactive tools that let farmers leverage new policies to improve their operations.

RESEARCHER
Scott Irwin, PhD

FUNDING
USDA Chief Economist's Office and others

Disseminating research has always been a priority for USDA. Over the years, however, the extension service evolved into something that Dr. Scott Irwin refers to as the "Big Silo High Touch" model.

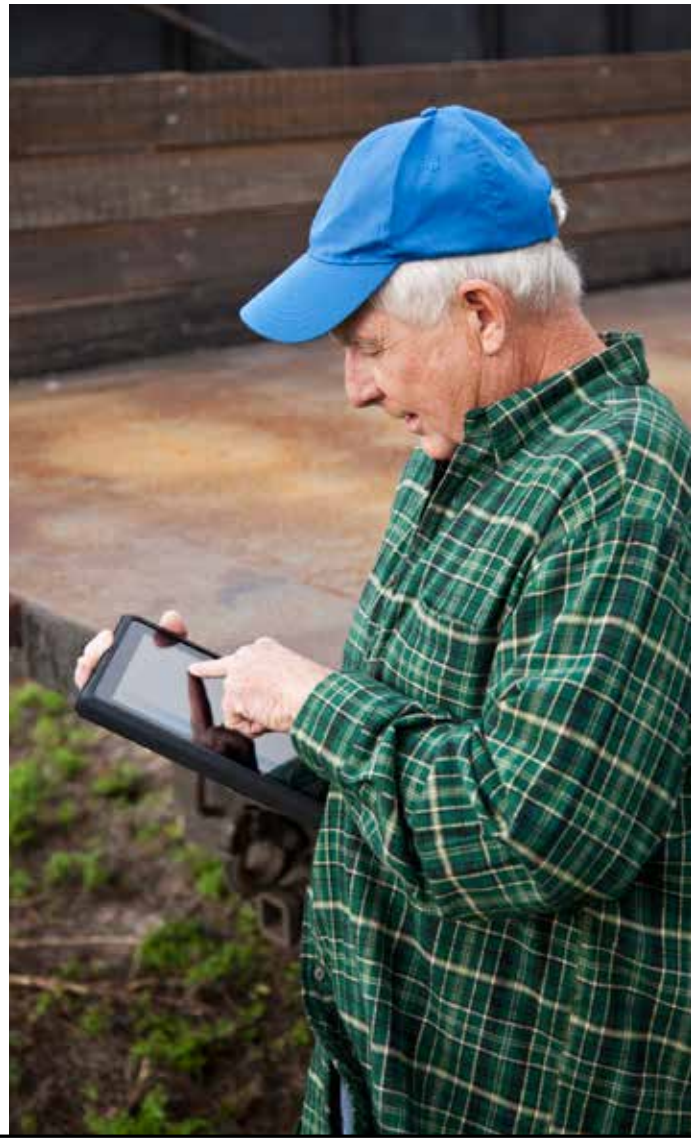
In this model, problems percolate from farmers through their local organizations to state extension specialists, who then identify a USDA researcher who can solve the problem. The specialists then create educational programs with the organizations to relay solutions.

In 2008, Dr. Irwin and his colleagues took a shortcut by putting their research online. Their website, called Farmdoc, serves the "Corn Belt" agricultural community. Updated daily, it now has over one million annual visitors.

"Farmers tell us that they need to access information in their tractors—which are now GPS-guided. This is where they do their office work today." – SCOTT IRWIN, PHD

Farmdoc is a portal to information and decision tools. For instance, when the most recent Farm Bill cut subsidies programs and expanded crop insurance, Dr. Irwin's team developed an interactive online tool to help farmers make sense of the new system. The tool enables farmers to input data on their operations (similar to Turbotax®) to determine, based on projections and historical data, how to manage their businesses under the new policies.

Farmdoc is transitioning to Farmdoc Daily, a more mobile-friendly interface, so that its content and tools can be accessed anywhere. As information and farmer needs continue to evolve, Farmdoc will keep pace.



"An ounce of prevention is worth a pound of cure."

– BEN FRANKLIN, AUTHOR OF POOR RICHARD'S ALMANAC

RETAKING THE FIELD REQUIRES A SURGE IN FEDERAL FUNDING

"The past century's remarkable advances in agriculture have demonstrated how public support for agricultural research, education, and extension can enable talented U.S. scientists to improve food, nutrition, and agriculture."

This is how the National Research Council of the National Academies of Sciences began its 2014 report: *Spurring Innovation in Food and Agriculture*. The report is a thorough examination of the USDA's premier competitively awarded grants program, the Agriculture and Food Research Initiative (AFRI).

Few programs illustrate the challenges in science funding better than AFRI. Established as part of the 2008 Farm Bill, it is open to all universities and institutions. Although Congress authorized AFRI for $700 million annually, it has received less than half of this amount to date. As a result, only $270 million of the $1.4 billion in projects recommended for funding by AFRI's review panels in FY 2014 received support. The funding shortfall discards innovative solutions as well as support for a new generation of researchers.

University administrators are also struggling with securing adequate funding to maintain the facilities that are the bedrock of their invaluable research. A 2015 report found $8.4 billion in deferred maintenance at the agricultural schools of 91 universities, many of which were state land grant institutions.[20]

The problems facing farmers, consumers, and everyone in the food supply chain, are reaching critical mass. But our country's researchers are ready to solve these problems if provided the resources they need. This report only scratches the surface when it comes to describing the talent and innovation that American scientists can bring to bear on seemingly intractable problems.

Providing sufficient federal funding for the agricultural sciences enabled the U.S. to become the world leader in agriculture, as we saw with the surge of research investment during the Green Revolution.

It is time once again to grow more solutions on our own soil. It is time to retake the field.

---

20 http://www.aplu.org/projects-and-initiatives/agriculture-human-sciences-and-natural-resources/DeferredMaintenance_SchoolsofAg.pdf

ABOUT SoAR

The Supporters of Agricultural Research (SoAR) Foundation leads a non-partisan coalition working to educate stakeholders about the importance of agricultural research and focus more of our best minds on feeding America and the world. SoAR advocates for full funding for USDA's Agriculture Food and Research Initiative (AFRI) to encourage top scientists from multiple disciplines to address agriculture-related challenges in order to improve public health and strengthen our economic competitiveness.

SoAR PARTNERS

Agricultural & Applied Economics Association
American Association for the Advancement of Science
American Farm Bureau Federation
American Society for Horticultural Science
American Society for Microbiology
American Society for Nutrition
American Society of Agronomy
American Society of Plant Biologists
American Soybean Association
American Veterinary Medical Association
Association of American Universities
Association of American Veterinary Medical Colleges
Association of Public and Land-grant Universities
Center for Foodborne Illness Research and Prevention
Consumer Federation of America
Crop Science Society of America
Federation of American Societies for Experimental Biology
Global Harvest Initiative
National Association for the Advancement of Animal Sciences
National Coalition for Food and Agricultural Research
National Corn Growers Association
National Pork Producers Council
Soil Science Society of America

Cornell University

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

IOWA STATE UNIVERSITY

KANSAS STATE UNIVERSITY

Massachusetts Institute of Technology

NC STATE UNIVERSITY

PURDUE UNIVERSITY

Stanford

TUSKEGEE UNIVERSITY

UCDAVIS
UNIVERSITY OF CALIFORNIA

UF UNIVERSITY of FLORIDA

University of Nebraska Lincoln

Washington University in St. Louis

1235 S. Clark Street
Suite 510
Arlington, VA 22202
571-257-7625

www.supportagresearch.org

SoAR
FOUNDATION