United States Department of Agriculture

AGRICULTURAL RESEARCH SERVICE 2017 ANNUAL REPORT ON SCIENCE

RESEARCH TO DEVELOP AND TRANSFER SOLUTIONS TO AGRICULTURAL PROBLEMS

www.ars.usda.gov

ABSTRACT

U.S. Department of Agriculture, Agricultural Research Service. 2018. Agricultural Research Service 2017 Report on Science. Washington, D.C.

This publication is the Agricultural Research Service's 2017 annual report on science, composed of numerical research outputs for the agency, accomplishments and impacts for each goal in the ARS 2012-2017 Strategic Plan, and ARS' performance plan for 2018.

Additional copies of this Report on Science can be downloaded from www.ars.usda.gov.

TABLE OF CONTENTS

INTRODUCTION

The Agricultural Research Service (ARS) is the U.S. Department of Agriculture's (USDA) chief in-house scientific research agency. Each day, more than 2,000 ARS scientists at more than 90 research locations, including overseas laboratories, discover real-world solutions to America's agricultural challenges.

Our unique capacity to conduct research that has an impact on the food we eat, the water we drink, and the air we breathe makes ARS one of the world's premier scientific organizations and a recognized champion of integrated research targeting national and regional agricultural priorities.

ARS' mission is to conduct research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to:

- Ensure high-quality, safe food, and other agricultural products;
- Assess the nutritional needs of Americans;
- Sustain a competitive agricultural economy;
- Enhance the natural resource base and the environment;
- Provide economic opportunities for rural citizens, communities, and society as a whole; and
- Provide the infrastructure necessary to create and maintain a diversified workplace.

The ARS vision is to lead America towards a better future though agricultural research and information.

ARS' Strategic Plan for FY 2012-2017 describes the Agency's research, program management, administrative management, and civil rights and diversity goals. It also crosswalks ARS' priorities to those of the Department and of the Research, Education, and Economics Mission Area.

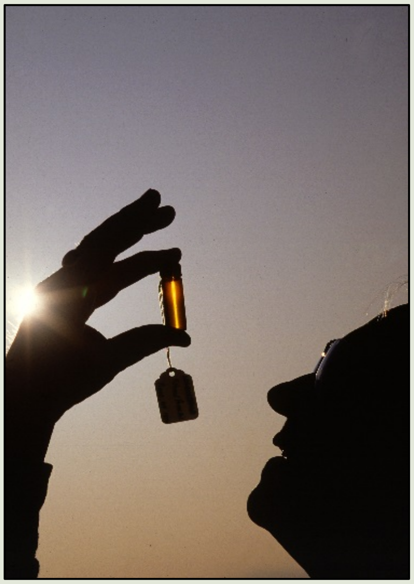
ARS organizes its research activities into 16 National Programs that are part of one of four broad Strategic Goal Areas:

- Nutrition, Food Safety and Quality;
- Natural Resources and Sustainable Agricultural Systems;
- Crop Production and Protection; and
- Animal Production and Protection.

The specific research goals for each of the four Strategic Goal Areas are developed after consultation with customers, stakeholders, and scientists and are described in each National Program's Action Plan—these form the basis for the research component of ARS' Strategic Plan. A full description of ARS' 5-year National Program Cycle, based on Relevance, Quality, Performance, and Impact, can be found in Appendix 1.

This Annual Report on ARS science describes progress made in Fiscal Year (FY) 2017 on the research goals described in the Strategic Plan in sections that address the Agency as a whole and for the specific Strategic Goal Areas. It also delineates the Agency's research performance plan for FY 2018-2020.

ARS ANNUAL REPORT ON SCIENCE



The impacts of agricultural research occur on a continuum that begins when new knowledge is captured in scientific publications and databases. Some of that knowledge can be directly transferred into use by means of trade journal publications and outreach activities. Other knowledge requires additional research, often collaboratively with industry and other partners, to develop products. Some of these products are released by ARS into the public domain and some require intellectual property protection and licenses as incentives for utilization through commercialization. These types of research outputs can be measured quantitatively and are listed under Research Outputs below. The ARS Section of the USDA Annual Report on Technology Transfer more fully describes the Agency's technology transfer accomplishments.

Any measure of successful ARS research would have to include its positive impacts on U.S. and global agriculture, a safer and more nutritious food supply for the nation and the world, and reduced environmental impact by food production. Outcomes and impacts of ARS research realized in FY 2017 are documented for each ARS research goal.

In this document, ARS has integrated its performance plan, which describes specific research targets for the next 3 years, with its annual report, which describes what was accomplished for last year's research targets and why those accomplishments are important.

ARS Research Outputs in FY 2017

Scientific Knowledge	4,013 Peer-reviewed journal articles	
Knowledge Transfer	62	Trade journal publications
	1,350	Outreach activities
	101	New Material Transfer Research Agreements
	445	New outgoing Material Transfer Agreements
	57	New Cooperative Research and Development Agreements
	101	Patent applications filed, 62 new patents issued
	38	New licenses, total of 426 active licenses

Preparing the Next Generation	2,200	Students associated with ARS research
	87,000	Students reached in 770 events: student tours, science fairs, presentations to schools
	320	Students mentored
	475	Postdoctoral scholars

Progress on Emerging Priorities in FY 2017

Agriculture is dynamic, driven by environmental, biological, economic, social, and technological change. New capabilities are realized and new threats emerge. In FY 2017, ARS initiated or continued progress on the following emerging priorities.

ARS GRAND CHALLENGE 20/20/25

In FY 2015, ARS accelerated its pursuit of innovation to propel U.S. agriculture into the future. We wanted to develop a new way of thinking about how we do our science, something that could be a catalyst for breakthrough innovation. An aspirational goal was collectively set – *Transforming Agriculture to Deliver a 20 Percent Increase in Quality Food Availability at 20 Percent Lower Environmental Impact by 2025*. This Grand Challenge recognizes the many pressing issues facing U.S. agriculture and that these issues are inextricably linked. In the minds of farmers, consumers, and citizens, having sufficient food to meet a growing population, ensuring it is of wholesome quality, and addressing agriculture's substantial environmental footprint are inseparable needs. To address them holistically, ARS research leadership designed an innovative mechanism to foster research collaborations that cut across disciplines, projects, and locations, enabling synergistic, system-level solutions to complex agriculture problems.

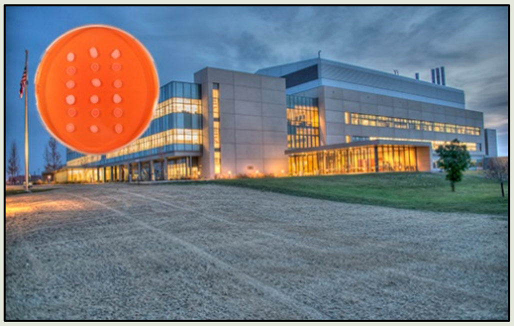
In FY 2017 the Grand Challenge initiative took off with three flagship projects that are pioneering this collaborative mechanism. All three projects assemble strong interdisciplinary teams to deliver system-level solutions addressing a single complex problem.

The Dairy Agriculture for People and the Planet Grand Challenge project centers on delivering nutrient dense dairy products with low environmental footprint. This project brings together dairy scientists, food technologists, and soil biologists, and is creating crosstalk among complex databases that have never interconnected before.

The Vesicular Stomatitis as an Illustrative Example for a Predictive Disease Ecology Grand Challenge project centers on delivering advanced predictive analytics that streamline the prevention and rapid response to animal infectious diseases. The project is enabling the integrated analysis of previously-unrelated flows of big data capturing the genetic and ecological determinants of vesicular stomatitis, a disease that affects cattle, swine, and horses.

The Solving the Citrus Greening Problem Grand Challenge Project is set to enable the recovery or re-invention of sustainable citrus production in the presence of citrus greening. The project team draws upon frontier technologies of vector population management, pathogen control, disease symptom mitigation, delivery systems for inputs, and new germplasm to find ways of controlling this critical and rapidly spreading invasive disease.

ANTIMICROBIAL RESISTANCE



Antimicrobial resistance (AMR) has been an area of focus during the past two decades for USDA, which plays a dual role in protecting animal agriculture and public health. Growing concern regarding antimicrobial resistance led to development of the *USDA Antimicrobial Resistance (AMR) Action Plan* and Executive Order 13676, *Combating Antibiotic-Resistant Bacteria*. The *National Action Plan for Combating Antibiotic Resistant Bacteria* was published on March 27, 2015 and identified the following goals:

1. Accelerate basic and applied research and development;
2. Slow the emergence of resistant bacteria and prevent the spread of resistant infections;
3. Strengthen national "One Health" surveillance efforts;
4. Advance development and use of rapid and innovative diagnostic tests; and
5. Improve international collaboration and capacities.

The following accomplishments addressing antimicrobial resistance were realized in 2017.

ARS examined whether livestock-associated (LA)-methicillin-resistant *Staphylococcus aureus* (MRSA) is a risk for humans. The study concluded that swine LA-MRSA isolates exhibited resistance to fewer antibiotics than MRSA isolates from humans. Furthermore, differences in the antimicrobial resistance genes between swine LA-MRSA and human clinical MRSA suggest LA-MRSA may not be a common zoonotic threat.

ARS examined whether certain probiotic *Bacillus* strains could serve as alternatives to antibiotics. Results from these studies showed that these probiotics stimulate innate host immune responses, reduce harmful inflammatory responses, and promote gut integrity when used as a feed additive in young chickens. These results provide scientific evidence for the beneficial effects of probiotic bacteria and the potential use of *B. subtilis* as a feed additive to promote gut health in commercial poultry production and reduce the use of medically important antibiotics.

ARS determined the prevalence and concentration of antimicrobial resistant bacteria and the levels of 10 antimicrobial resistance genes in ground beef and pork chops from food animals either raised without antibiotics or conventionally. Generally, antimicrobial resistance levels were similar between meats from animals raised with and without antimicrobials. These results demonstrate that there is no greater risk of human exposure to antimicrobial resistance between beef and pork products raised with antibiotics and those raised without antimicrobials.

ARS compared the occurrences of resistance to antimicrobials in bacteria from beef cows for which complete antimicrobial treatment records were available. The studies found that the occurrence of antimicrobial-resistant bacteria was not associated with, or predicated on prior history of antimicrobial treatments or duration of time since the last antimicrobial treatment. Other unknown factors more strongly influenced the observed levels of antimicrobial-resistant bacteria in beef cows.

ARS found the bacterial gene (*mcr-1*) that codes for colistin resistance in livestock. Colistin is an antibiotic classified by the World Health Organization as being of critical importance to human health. This was the first detection of the *mcr-1* gene in the United States, and at this time, it is unknown how the resistance gene traveled from China to the United States.

CLIMATE CHANGE

The vision of the USDA Climate Change Science Plan is empowering farmers, foresters, ranchers, land owners, resource managers, policy-makers, and Federal agencies with science-based knowledge for managing the risks, challenges, and opportunities of climate change, including positioning them to reduce atmospheric greenhouse gas emissions and enhance carbon sequestration. ARS has a broad portfolio of research that supports Departmental goals for resilient crop and livestock production systems adapted to changing climate patterns and dynamics.

In FY 2017, ARS scientists:

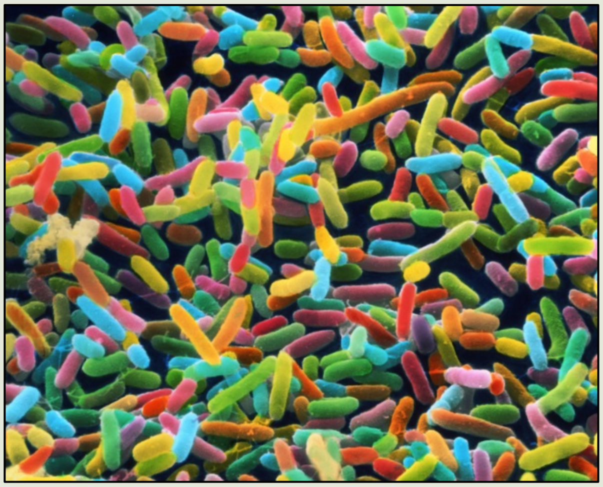
1. Developed or enhanced technologies and management systems that reduce emissions of nitrous oxide, carbon dioxide, and methane;
2. Developed or enhanced technologies and management systems that increase the sequestration of atmospheric carbon, resulting in the storage of more carbon in soils, biomass, and bio-based products;
3. Improved management systems that build soil health and climate resiliency, which helps landowners adapt to weather extremes and changing climatic conditions; and
4. Provided improved measurement and monitoring, resulting in better data and enhancing the ability to quantify and inventory GHG emissions and carbon storage at local to national scales.

Nitrous oxide (N_2O) emissions significantly contribute to global warming and emissions have increased worldwide over the past few decades. N_2O is emitted from agricultural settings, notably from cattle manure and fertilized soils. N_2O losses from fertilizer are considered to be agriculture's overall largest contributor to global warming; in addition, these losses are concerning because nitrogen that would otherwise be available for plants is lost via the emissions. ARS researchers at Auburn, Alabama, identified and developed microbial inoculants that reduce N_2O losses from nitrogen fertilizers and improve plant production and plant nutrient efficiency. These microbial inoculants have been patented and are available to producers for reducing N_2O emissions and providing these other beneficial outcomes in production agriculture.

Researchers have traditionally used chambers that cover the emitting surface to measure N_2O emissions. This process allows several gas samples to be collected over a 30 to 60 minute period, but it does not provide continuous data about N_2O emissions over time. ARS scientists from Bushland, Texas, and scientists from Texas A&M AgriLife Research developed an improved method that incorporates a real-time, continuous N_2O analyzer and accurately measures N_2O emissions from manure and soil in only 60 seconds. The improved method resulted in faster and more accurate measurements of greenhouse gas emissions from manure and led to new findings about processes associated with N_2O emissions, which may help producers mitigate emissions.

Soil organic carbon (SOC) must be maintained or increased to ensure crop productivity and soil health. But SOC levels in the Pacific Northwest dryland production region has greatly declined in the past few decades because of intensive tillage, low biomass inputs, fallow production, and straw burning. In the early 1980s, ARS researchers in Pendleton, Oregon, measured SOC in crop fields to a depth of 60 inches, and repeated their measurements in the early 2000s. They found that cropping with winter wheat and peas increased deep SOC the most, while enrolling fields in the Conservation Reserve Program and cropping with winter wheat and reduced tillage also increased deep SOC. These results can be used to encourage producers to use deep-rooted legumes such as peas as rotation crops, and to reduce the use of tillage and fallow for sustainable wheat production.

MICROBIOME



The National Microbiome Initiative (NMI) was launched by the White House Office of Science and Technology Policy (OSTP) in 2016 to advance the understanding of microbiomes–communities of microorganisms (bacteria, viruses, and fungi) that live on or in people, plants, animals, soil, oceans, and the atmosphere–for applications in health care, food production, and environmental management. Microbiomes promote the healthy functioning of diverse ecosystems, and affect human and animal health, crop and soil health, climate change, and other complex systems. By contrast, dysfunctional microbiomes are associated with human chronic diseases such as obesity, diabetes, and asthma; reductions in agricultural productivity; and local ecological disruptions such as the hypoxic zone in the Gulf of Mexico. New technologies enable ARS scientists to make breakthrough discoveries about the importance of microbiomes and the knowledge to better manage microbiomes in a manner that prevents dysfunction or restores healthy function.

The following noteworthy research results by ARS scientists were realized in FY 2017.

The increasing trends of legislative restrictions and voluntary removal of antibiotic growth promoters worldwide has impacted poultry production and poultry health. For example, the rising incidence of *Clostridium* infections and development of *Clostridium perfringens* (CP)-caused necrotic enteritis (NE) in chickens is associated with the withdrawal of antibiotics during production. Normal animal intestinal populations, or microbiomes, play an important role in the maintenance of host health by providing energy, nutrients, and immunological protection. The balance among intestinal microbiota can be disrupted by the use of antibiotics, diets, and harmful bacteria that cause infections. ARS scientists used gene sequencing technology to investigate the presence of specific changes in the gut microbiota following parasite and bacterial infections in chickens. Using this technique, they identified unique alterations in gut bacterial population following infections with bacteria *Clostridium perfringens*, parasites called Eimeria, or antibiotic treatments. Investigating how various treatments affect gut microbiota and host disease response will lead to the development of improved production practices.

USDA and U.S. Department of Health and Human Services (HHS) Dietary Guidelines for Americans recommend replacing refined grains with whole grains to maintain health and reduce the risk of disease. However, the evidence for this can be inconsistent. ARS scientists studied 81 older volunteers who were given meals for 6 weeks designed to maintain body weight. These meals contained either 0 or 7 ounces of whole grain foods daily. The study showed that whole grain intake promotes greater net energy loss (92 calories/day) compared to refined grains. There were also modest beneficial changes in the large intestine microbiome and in two types of immune cells in the bloodstream. By showing the benefits of whole grains on energy balance and systemic immunity, these data further strengthen USDA and HHS recommendations to use whole grain foods for at least half of grain servings.

For many decades, methyl bromide was employed as a powerful wide-spectrum fumigant to control many agricultural pests and pathogens, such as apple replant disease. But methyl bromide was found to deplete the ozone layer, and its use is now restricted in the United States and other countries. One of the most promising alternatives is anaerobic soil disinfestation (ASD), a process that temporarily removes oxygen from the soil and promotes microbiome activities that are toxic to or suppress many soil borne pests and pathogens. Field trials by ARS scientists show that the choice of organic matter, such as orchard grass, is a highly effective and inexpensive source of carbon for the ASD process and that control of apple replant disease using orchard grass was equivalent to that attained using chemical pre-plant soil fumigation, even for apple cultivars that are susceptible to replant disease. ARS scientists demonstrated that amending the soil with a formulation of *Brassica* seed meal to improve the ASD process also activates and increases the plant's own baseline resistance response to apple replant disease. Although different apple rootstocks responded differently to the *Brassica* seed meal treatment, replant disease was effectively controlled throughout the trials. These studies show that ASD could become a reliable and cost-effective alternative to conventional soil fumigation.

Agricultural Resources and Research Tools

ARS maintains a number of key resources supporting global agricultural research—and global agriculture itself. These resources include unique and invaluable collections of plant and animal germplasm, including heritage and pre-agricultural species and wild relatives of crops from all over the world. These provide the seed stock and clones for agricultural research, preserve agricultural genetic diversity, and are a critical reserve of the world's agricultural plants and animals. Likewise, ARS maintains one of the largest public collections of microorganisms in the world— both pathogens and microorganisms instrumental to the growth of healthy plants and animals.

ARS is also a trusted source of key, publicly accessible data. ARS databases include food composition databases that are the standard reference for producers, researchers, and nutritionists; databases of plant and animal genomic and phenotypic information; and long-term environmental databases on soils, watersheds, and climate.

The National Agricultural Library (NAL) is one of four national libraries of the United States and houses one of the world's largest collections devoted to agriculture and related sciences. NAL maintains collections of agricultural books and journals, and also has applied library science to the digital world, creating an Ag Data Commons and public information sites on a variety of agricultural and research topics.

ARS also maintains publicly available scientific models and software that are used by scientists and end users to model crop and farm production and management, water resources use and management, pest management, plant and animal growth, and research calculations.

AGRICULTURAL RESOURCES AND RESEARCH TOOLS – 2017 ACCOMPLISHMENTS

ARS has a large and important collection of animal genetic resources that has been used to regenerate or analyze important lost animal genetic resources. For example, Purdue University acquired pig germplasm samples from the stored collection to reconstitute a research line of pigs that was no longer available. The Angus Association obtained a stored semen sample from a prominent bull and determined that the bull was free of a lethal mutation; this meant the Association did not have to genotype more than 29,000 other cattle, saving approximately $2 million. Collaborative research between ARS scientists in Fort Collins, Colorado, and researchers at Pennsylvania State University, determined there were only two different Y chromosomes (which determines whether an animal is male) in the current U.S. Holstein population (our major milk producing breed) and that there were two additional Y chromosomes in semen stored in the collection that were not identified in the present Holstein population. ARS and Pennsylvania State University scientists worked with industry to produce bull calves with these two lost Y chromosomes from the collection as a first step to re-introducing them to increase genetic diversity. These examples demonstrate the value of the germplasm collection to the U.S. livestock sector as a tool that industry and researchers can use in their efforts to solve a range of livestock industry problems.

The Grasshoppers: Their Biology, Identification and Management website and CD collection includes a grasshopper identification key and field guides, decision support software, practical management information, and frequently updated grasshopper and Mormon cricket survey/forecast maps. This resource was created by ARS scientists in Sidney, Montana, and APHIS scientists. It has already been used by more than 800 pest managers as part of USDA-APHIS-PPQ sponsored "Train-the-trainers grasshopper IPM" workshops. Approximately 7,000 customers have requested copies of the CD-ROM. The website is in the top search results for grasshopper management related terms. Before the development of this website, land managers did not have access to timely information on grasshopper outbreaks.

ARS manages the website for FORMIS, a master bibliography of ant literature. This online searchable database is comprised of over 50,000 citations for the efficient and effective exchange of scientific literature about ants. It has about 300 registered users from dozens of countries

Whereas computer-aided simulation may be useful in designing optimal breeding strategies, the complexity of simulation is a barrier for breeders to taking the first step in using the software. ARS researchers in Ithaca, New York, developed a simple and flexible computational software suite called the breeding scheme language (BSL), which allows users to more easily simulate breeding options and estimate the benefit from selection under specific genetic criteria and options. This software will be useful for breeders for evaluating breeding schemes and selecting optimal breeding strategies, and also serves as a training platform for plant breeders.

How is the USDA continuing to improve agricultural management and improving the overall environmental footprint of agriculture? The answer is through activities and efforts of its expanding GRACEnet (the Greenhouse gas Reduction through Agricultural Carbon Enhancement Network) group of scientists and locations. This community has greatly expanded its roles in these efforts by establishing new field and laboratory measurement protocols, refining and simplifying how data are shared, developing and implementing software tools that perform data entry quality control, and introducing a web-accessible GRACEnet database. As a result, GRACEnet's web portal now contains data from 17 ARS locations with more than 450,000 records, including 116,000 soil greenhouse gas (GHG) emission measurements and 83,000 soil measurements. These data are being used to increase the accuracy of GHG emission estimates reported in the U.S. national GHG inventories, including the latest EPA inventory published in FY 2017.

Mathematical models are frequently used to predict the growth and survival of microorganisms in food throughout the supply chain and are the foundation of quantitative microbiological risk assessment. Accurate estimation of kinetic parameters is essential to predictive modeling. ARS researchers in Wyndmoor, Pennsylvania, have expanded the USDA IPMP–Global Fit, a one-step kinetic analysis software for predictive modeling. Growth and survival models are included in the new software for direct construction of predictive models that minimize global errors. This new approach to mathematical modeling can significantly improve the accuracy of data analysis and future model development. IPMP–Global Fit can be downloaded from the web and is free for researchers and risk modelers around the world to use.

Bees play a crucial role in U.S. agriculture as pollinators of many important crops. ARS scientists in Beltsville, Maryland, collaborated with researchers at the University of Michigan and USDA-APHIS on designing an interactive web based identification tool to identify mites that can be found on bees in bee colonies. The website will help beekeepers and bee biologists distinguish between harmful and harmless mites. The searchable image gallery contains over 850 mite images, which makes it possible to compare images from many different types of mites. This website covers bee-associated mite genera from around the world, with an emphasis on those associated with important pollinators, including honey bees, mason bees, bumble bees in temperate regions, and stingless bees and large carpenter bees in the tropics. This interactive key is useful to bee keepers, scientists, extension agents, and quarantine officers worldwide.

ARS manages a public website on Rift Valley fever epidemiology and vector biology, including Rift Valley fever surveillance and risk transmission in endemic regions. Risk prediction allows early warning for potential outbreaks and is used by public and veterinary health officials, livestock owners and managers, vector control professionals, and disease modelers. Early advance warning of an outbreak allows for personnel to effectively distribute vaccines, educate and train, and perform vector control measures in areas of and during times of increased transmission risk.

International Collaborations

In recognition that agriculture, and agricultural research, is now a global enterprise, ARS' international office is working to enhance the productivity, effectiveness, and impact of ARS National Programs through mutually beneficial international research activities. The United States directly benefits from international collaboration in agricultural research through access to new ideas and technologies, global germplasm collections, crucial international foreign research sites, enhancement to domestic research, and increased trade. The increasingly transboundary nature of many agricultural problems, such as emerging and re-emerging plant and animal diseases; control of invasive species through discovery and importation of biological control agents; scientific collections, including genetic resources preservation; and the need to increase productivity to ensure adequate supplies of agricultural products, provides a strong incentive for greater international cooperation. International agricultural research cooperation addresses global food security by providing solutions to current and future agricultural productivity and sustainability challenges. By sharing knowledge and technology through close cooperation with national and international research institutions in other countries, ARS collaborations enhance international relationships, increases institutional research capacity, and speeds technology development.

ARS participated in 1,892 foreign research collaborations with 125 countries (shaded in blue) in 2017:

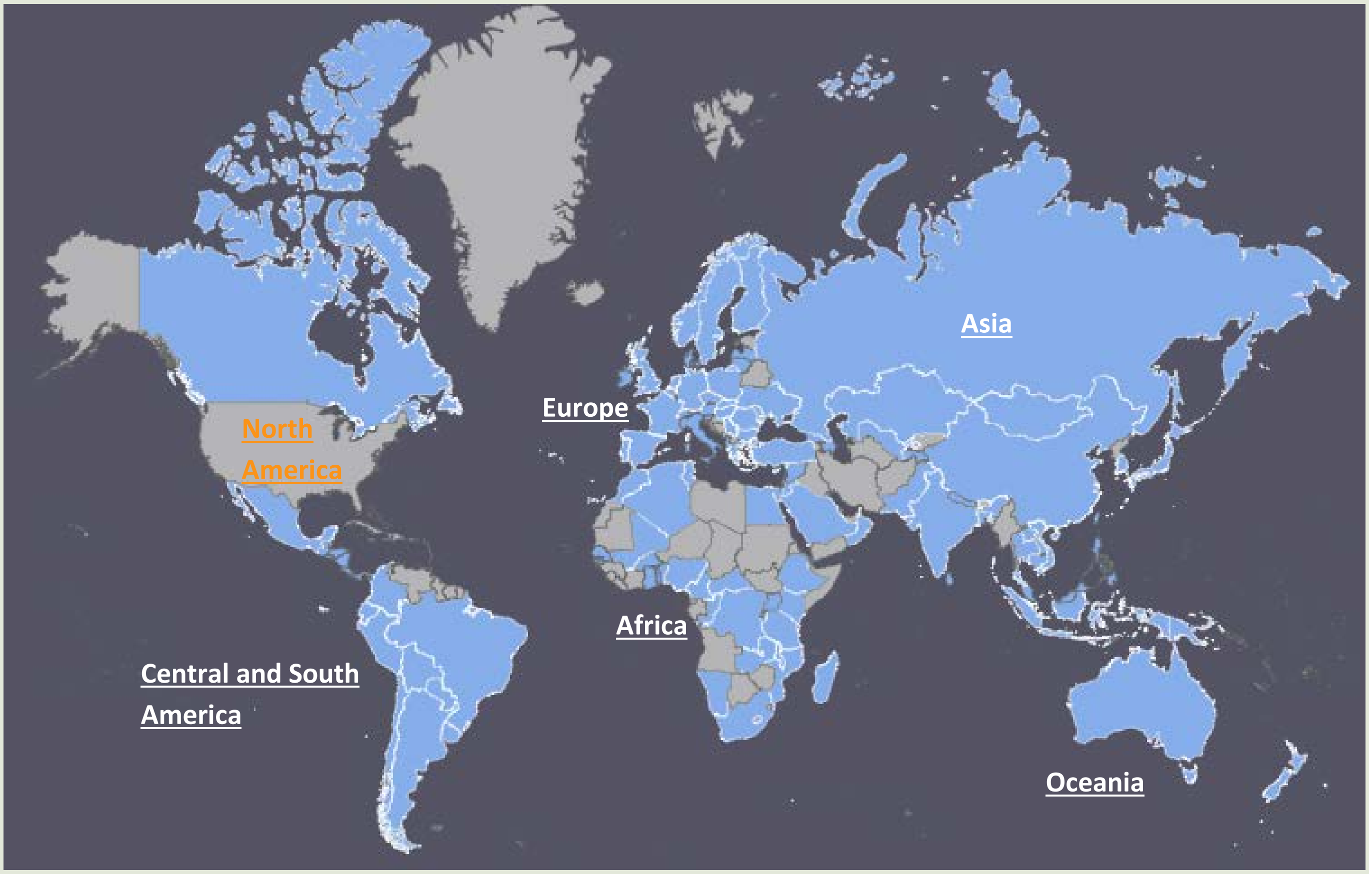


Figure 1 - ARS collaborated with scientists in the blue-shaded regions. Click on a region name to view a table listing the number of collaborations with each country in that region.

GOAL AREA 1: NUTRITION, FOOD SAFETY, AND QUALITY

The Nutrition, Food Safety, and Quality research and information area exists to lead and coordinate ARS research and information dissemination to define the role of food and its components in optimizing health for all Americans; develop tests and processes that keep the food supply safe; reduce and control pathogens and toxins in agricultural products; and improve the economic viability and competitiveness of American agriculture by enhancing the quality and utilization of agricultural products for the benefit of producers and consumers.

Goal 1.1 – Enable Americans to Make Health-Promoting, Science-Based Dietary Choices

NATIONAL PROGRAM 107 - HUMAN NUTRITION

To improve the nutrition and health of the American people, ARS conducts research on the quality of the American diet and on related health behaviors. Distinctive aspects of this research include an emphasis on a food-based approach to improving health; the core capability to sustain long-term research in areas deemed of high priority for the Nation's health; the availability of state-of-the-science equipment and facilities for human research across the lifecycle; and the conduct of multidisciplinary research to improve the nutritional value of the American diet and food supply. The mission of the Human Nutrition Program is to define the role of food and its components in optimizing health throughout the life cycle for all Americans by conducting high national priority research. This research emphasizes study of essential nutrients and nonessential, health-promoting components in foods; evaluating the nutritional value of diets eaten by people in America; determining how consumption of specific foods or food components can enhance health; and developing strategies to improve food choices and lifestyle factors. Increasingly, research focuses on addressing over-consumption and caloric imbalance with incorporation of cutting-edge genomic and metabolomic technologies to carry out research. Research addresses four overarching components: nutrition monitoring, the scientific basis for dietary recommendations, obesity prevention, and life stage nutrition and metabolism. Information dissemination programs operated by the National Agricultural Library address general and specific human nutrition issues and audiences and include general Web portals such as www.nutrition.gov as well as the targeted Web sites of the Food and Nutrition Information Center.

PERFORMANCE MEASURE FOR GOAL 1.1

Monitor nutrient composition of food supply and consumption by Americans while conducting research on life stage nutrition and metabolism. Strengthen the scientific basis for dietary guidance for health promotion and disease prevention and develop strategies for prevention of obesity and related diseases.

FY 2017 PERFORMANCE REPORT FOR GOAL 1.1

Indicator 1: During 2017, ARS will survey, release data on, and analyze national food consumption patterns of Americans**.**

Sugar has replaced fat in recent years as a focus of recommendations to restrict intake, despite relatively weak evidence for recommendations to reduce sugar intake. Essential data in this debate is knowing how much is being consumed. ARS scientists in Beltsville, Maryland, used *What We Eat in America* data from NHANES 2013-2014 and found that more than 40 percent of Americans meet the *Dietary Guidelines for Americans* by consuming no more than 10 percent of calories from added sugars, with a higher proportion of children not meeting that limit. In addition to age, ethnicity was a factor in sugar intake but household income was not.

What this means: As a group, Americans reduced their sugar intake from 2003-2004 to 2013-2014 by three and a half teaspoons daily. This was accompanied by a reduction in solid fats and a very small but statistically significant increase of whole grains intake. All of these changes indicate improvements in dietary intake.

Limited data exist on beverage intake among U.S. children between birth and 24 months of age. Since the *2020 Dietary Guidelines for Americans* will be expanded to included children under the age of 2 years, ARS supported scientists in Houston, Texas, in collaboration with colleagues from Deakin University in Australia, used NHANES data on beverage intake from over 2,700 children. In infants under 1 year of age, infant formulas were the most common beverage, consumed by with three of four children. Far fewer infants consumed breast milk (42 percent before 6 months and 24 percent from 6-12 months). In toddlers, 12-24 months old, the most common beverages were plain milk (84 percent), water (69 percent), 100 percent fruit juice (52 percent), and sweetened beverages (31 percent). Children from lower income households and certain ethnic minorities were more likely to consume sweetened beverages and fruit juice and less likely to consume breast milk.

What this means: Disparities in beverage consumption are apparent early in life. These data establish baseline intake from which recommendations can be made for healthier choices in this age group.

Indicator 2: During 2017, ARS will develop new methods, conduct food composition analyses, and compile databases for known, emerging, and new classes of nutrients and for branded food items.

It is important to know the concentration of nutrients in human milk because it is recommended as the sole source of nutrition for infants during the first 6 months of life. Additionally, it is the basis for setting nutrient intake recommendations for infants, nursing women, and young children. Unfortunately, the reported nutritional values for human breast milk are few and inconsistent across studies due to differences in methods and timing of milk collection and maternal nutritional status. ARS researchers in Davis, California, developed and validated more efficient methods for measuring nutrients in human milk. These new methods spawned a new study to obtain reference values for nutrients and other milk components in four countries. The studies showed that poor maternal nutritional status and/or dietary quality results in low concentrations of many nutrients in milk, and that various ways of improving a mother's micronutrient status can increase the micronutrient concentrations in milk.

What this means: This research will be useful for improving nutrient intake recommendations for infants, lactating women, and young children, and for informing global public health policy about the need for maternal or infant supplementation during lactation.

Indicator 3: During 2017, ARS will identify dietary and lifestyle intervention strategies to prevent obesity and promote healthy food choices and eating behaviors.

Dietary recommendations, including Dietary Guidelines for Americans, suggest replacing refined grains with whole grains, but the evidence for supporting this recommendation is not consistent. ARS-supported scientists in Boston, Massachusetts, studied 81 older volunteers who were given meals for 6 weeks. These meals contained either 0 or 7 ounces of whole grain foods daily and were designed to maintain body weight. Whole grain intake led to a 92 calorie/day higher net energy loss compared with refined grain intake. There were modest beneficial changes in some of the large-intestinal bacteria and two types of immune cells in the bloodstream as a result of this diet.

What this means: These data strengthen the recommendation from the Departments of Agriculture and Health and Human Services that at least half of a person's grain servings should come from whole grain foods.

Almost all dietary recommendations worldwide, including the *Dietary Guidelines for Americans*, emphasize increased fruit and vegetable intake but few populations achieve the recommended intake levels. A group of 740 participants in the Farmers' Market Nutrition Program in urban New Jersey received a single web-based lesson to promote fruit and vegetable consumption and cash value vouchers. Although knowledge of the items available at markets increased and modest gains occurred in voucher redemption, fruit/vegetable intake did not improve over time.

What this means: The results suggest limited education is insufficient to increase healthier choices and that other options need to be identified for improving U.S. diets.

Indicator 4: During 2017, ARS will determine the functions, bioavailability, interactions, and requirements for known, emerging, and new classes of nutrients across the lifecycle.

The glycemic index (GI) was developed to identify how specific carbohydrate-rich foods influence blood sugar levels in the hours after consumption. Glycemic load (GL) incorporates both the GI and quantity of food to adjust for serving size. These measurements did not consider how blood sugar levels are affected when carbohydrate-containing foods are eaten in combination with other nutrients such as fat or protein. ARS-funded researchers in Boston, Massachusetts, found that adding protein to a person's diet resulted in a significant reduction in measured GI and GL that is presumably healthier, while adding carbohydrate, fat, or fiber had little effect on these values.

What this means: These data indicate significant variability in meal GI and GL determinations results from the consumption of different food combinations and caution against using these values for dietary guidance.

Many seniors take supplements of vitamin D because deficiency has been associated with an increased risk of falling. Vitamin D supplements are usually taken daily, but less frequent dosing would be more convenient for many older individuals. A human clinical trial conducted by ARS-funded researchers in Boston, Massachusetts, in collaboration with colleagues at the University of Zurich, assessed the effectiveness of taking different doses of vitamin D monthly on the risk of falling in older community-dwelling men and women. A higher monthly dose was equivalent to 2,000 IU per day, and a lower dose was equivalent to the standard dose of 800 IU per day. Over the 1-year follow-up period, there were significantly more falls among individuals in the high-dose group compared with those in the standard dose group.

What this means: This study showed that high monthly doses of vitamin D are not warranted in seniors because of a potentially harmful effect of increased falls.

One in six Americans carries two copies of a genetic variant in the gene for a vitamin B12 transport protein. In a study of more than 170 older adults, ARS-supported scientists in Boston, Massachusetts, collaborated with colleagues from Boston University and Pfizer, Inc., and found that individuals with the gene variant were three times more likely to have a type of nerve damage called peripheral neuropathy. Subjects with the variant who consumed more than twice the recommended amount of folate were seven times more likely to develop peripheral neuropathy.

What this means: These results strongly suggest that older people should exercise caution in taking folic acid supplements and limit their folate intake to no more than the recommended amount.

Indicator 5: During 2017, ARS will publish new findings on metabolic processes that are affected by nutrient intake.

Nutritional supplements and physical activity have been prescribed to help older adults maintain muscle mass. However, the long-term effects of nutritional supplementation in combination with physical activity in older adults, particularly those with limited mobility, are not known. ARS-funded researchers in Boston, Massachusetts, conducted a nutritional study in older adults with limited mobility and vitamin D insufficiency in conjunction with a 6-month physical activity program. Throughout the 6-month program, one group consumed a daily nutritional supplement and the other consumed a placebo. Both groups lost body fat and increased thigh muscle size, but participants receiving the nutritional supplement lost more fat between muscles in the thigh and had a greater increase in muscle size than those receiving the placebo.

What this means: This study demonstrates that exercise and nutritional supplementation work synergistically to benefit muscle composition and mass in older adults with limited mobility.

Consumption of a diet that induces obesity in laboratory animals also increases development of colon cancer. The mechanism connecting diet to colon cancer has not been established. ARS researchers in Grand Forks, North Dakota, and University of Massachusetts collaborators found consuming diets that induce obesity increases inflammatory status and disease-causing bacteria in the colon of mice. The latter finding resulted from reduced levels of antimicrobial peptides released from the specialized cells lining the colon. The importance of the microbiota was seen in these results, driving intestinal inflammation that increases the risk of colon cancer. A second study with colleagues from the University of Vermont found feeding mice a high-fat diet to induce obesity increased cell growth and the expression of a gene commonly altered in colon cancer and also modified bacterial families in the colon.

What this means: Dietary changes are becoming increasingly recognized as major factors that can affect the metabolism of colon bacteria and associated changes in host health.

Researchers are attempting to determine if chronic circadian disruption alone leads to obesity and cancer. Scientists in Houston, Texas, conducted research that demonstrated chronic circadian disruption alone is sufficient to induce metabolic syndrome, fatty liver disease, and cancer in laboratory animals. Chronic circadian disruption affects the majority people in the United States due to lifestyle changes.

What this means: These findings advance efforts to understand how unhealthy lifestyle factors can increase the risk of obesity and cancer, and will lead to development of novel strategies for obesity and cancer prevention and treatment

Indicator 6: During 2017, ARS will discover genetic or epigenetic factors that influence physiologic responses to diet or changes in gene expression in response to dietary intake.

Chronic inflammation is at the crossroad of all major age-related diseases, such as atherosclerosis, cancer, obesity, and diabetes. Interleukin 6 (IL6) is one of several proteins circulating in the bloodstream induced during inflammation and previous research has shown that dietary factors, such as omega 3 fatty acids, improve inflammation status by reducing the levels of this protein. The hypothesis that omega 3 fatty acids affect expression of the IL6 gene was tested in a study of about one thousand individuals. DNA methylation of the IL6 gene affected blood levels of omega 3 fatty acids, and this methylation was dependent on the presence of different genetic forms of the IL6 gene.

What this means: These findings support the idea that dietary omega 3 fatty acids are effective at mitigating age-related diseases and provide a molecular mechanism of action via epigenetic control of gene expression leading to reduction in inflammation.

Indicator 7: During 2017, ARS will identify processes and methods whereby agriculture production influences the nutritional value of the food supply.

Dietary guidelines urge consumption of whole grains, yet it is often difficult to determine whether a food product is made from refined or whole grain foods. Moreover, depending on how they are grown, similar grains may have different chemical compositions. Consequently, it is in the interest of the food and agricultural sector to have an analytical method that accurately identifies and differentiates whole grain products from conventional food products made from refined grains. Scientists at Beltsville, Maryland, used standard chemistry analytical methods to differentiate the various fractions (bran, germ, endosperm, refined, and whole grain) in flours and processed foods. Results from these studies showed that compounds known as phenolic acids were present in higher concentration in whole grain.

What this means: These results show that chemical methods can be used to classify whole and refined grain products. This will allow standards to be established that ultimately can be used by both agricultural producers and the food processing industries.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 1.1

During FY 2018, ARS will:

1. Survey, release data on, and analyze national food consumption patterns of Americans.
2. Develop new methods, conduct food composition analyses, and compile databases for known, emerging, and new classes of nutrients and for branded food items.
3. Identify dietary and lifestyle intervention strategies to prevent obesity and promote healthy food choices and eating behaviors.
4. Determine the functions, bioavailability, interactions, and requirements for known, emerging, and new classes of nutrients across the lifecycle.
5. Publish new findings on metabolic processes that are affected by nutrient intake.
6. Discover genetic or epigenetic factors that influence physiologic responses to diet or changes in gene expression in response to dietary intake.
7. Identify processes and methods whereby agriculture production influences the nutritional value of the food supply.

During FY 2019, ARS will:

1. Collect and release data on national food consumption patterns of Americans and the chemical composition of those foods.
2. Identify dietary and lifestyle intervention strategies to prevent obesity and promote healthy food choices and eating behaviors.
3. Publish new findings on metabolic processes that are affected by nutrient intake.
4. Determine the functions, bioavailability, interactions, and requirements for known, emerging, and new classes of nutrients across the lifecycle.

During FY 2020, ARS will:

1. Collect and release data on national food consumption patterns of Americans and the chemical composition of those foods.
2. Identify dietary and lifestyle intervention strategies to prevent obesity and promote healthy food choices and eating behaviors.
3. Publish new findings on metabolic processes that are affected by nutrient intake.
4. Determine the functions, bioavailability, interactions, and requirements for known, emerging, and new classes of nutrients across the lifecycle.

Goal 1.2 – Protect Food from Pathogens, Toxins, and Chemical Contamination during Production, Processing, and Preparation

NATIONAL PROGRAM 108 – FOOD SAFETY

The safety of the food supply continues to be a highly visible public health issue and a national priority for the Federal government. The continued priority is partly due to the diverse and complex system of production, processing, and distribution of food in the United States and the increasing global distribution. Outbreaks of foodborne illness are seen as a major cause of morbidity and mortality and economic costs, both nationally and internationally. The full extent of the disease burden is still unknown, even with recent CDC estimates. Foodborne illnesses can be caused by microbial pathogens, parasites, viruses, and an array of foodborne contaminants such as chemicals or toxins. The cause of every outbreak is still unknown, but persistent outbreaks of major commodity-specific foods that may directly affect public health, regulations, industry, and trade require our immediate attention.

ARS has developed an integrated approach to food safety, that is, food production is seen as a continuous process from production through harvesting and processing to retail and the consumer. Pre- and post-harvest are not separated, but considered an integrated production system of safe and quality food. Interventions and controls that are applied to one phase will ultimately affect the other segments of food production and processing. Food safety research has also changed during the past decade, having moved past simple surveillance/prevalence studies to asking more complex questions. Consequently, researchers are required to think creatively to solve problems, which means considering alternate perspectives, exploiting new opportunities and technologies, and crossing conventional boundaries. Multidisciplinary collaborations, especially between Centers/Institutes nationally and internationally are an absolute necessity.

ARS provides the intramural infrastructure and expertise to address short- and long-term needs in food safety. Because of the infrastructure, ARS is uniquely poised to respond quickly to emerging and critical food safety issues. ARS also collaborates closely with Federal regulatory agencies as well as industry, professional, and international stakeholders to assist in addressing their specific food safety needs.

PERFORMANCE MEASURE FOR GOAL 1.2

Develop new technologies that assist ARS customers in detecting, identifying, and controlling foodborne diseases associated with the consumption of animal products that affect human health.

FY 2017 PERFORMANCE REPORT FOR GOAL 1.2 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will determine how population systems in animals, plants, or the environment, or any combination of these influence the safety of food. ARS will determine the conditions under which microorganisms exist. ARS will determine how microorganisms may in turn influence the conditions prevailing in the environment. ARS will ensure that these technologies can be utilized by regulatory agencies, producers, and/or processors to help assure safe food products.

Insect damage allows mycotoxigenic fungi to establish and grow on corn, leading to reduced yields and a crop that may be unsafe for humans and other animals. Plants release airborne chemicals (volatiles) in response to infection or attack by the caterpillars of insect pests. To determine whether these key plant defense signals are altered by changes in climatic conditions, ARS researchers in Peoria, Illinois, and Gainesville, Florida, compared the amounts of caterpillar-induced volatiles produced by sweet corn grown at ambient and elevated carbon dioxide levels. Corn grown in high levels of carbon dioxide released significantly lower concentrations of volatiles than corn grown in ambient levels.

What this means: Corn might become more susceptible to insect pests as atmospheric carbon dioxide levels increase. The study also resulted in the identification of a trait that can be used in plant breeding programs to improve the natural defense response of corn, which would result in increased yields, reduced mycotoxin contamination of grain, and limited use of pesticides.

In recent years, alternatives to conventional cage-based housing for poultry flocks has become more common in the commercial egg industry. But the effects of different housing systems on important public health problems, such as *Salmonella enteritidis* contamination of eggs laid by infected hens, are not yet fully understood. ARS researchers in Athens, Georgia, studied the frequency at which laying hens experimentally infected with *S. enteritidis* shed the bacterium in their feces. They found that hens housed in conventional cages shed *S. enteritidis* more frequently than hens housed in colony cages with perches and enclosed nesting areas. In this study, laying hens were housed in colony cages enriched with perches and enclosed nesting areas at two different stocking densities (defined by the amount of floor space available to each bird), or in conventional cages at a higher density. Both flocks were orally infected with *S. enteritidis*. Samples of voided feces were collected from trays beneath the cages at weekly intervals and tested for the pathogen. The frequency of *S. enteritidis* isolation from feces was significantly greater when infected hens were housed in enriched colony cages at higher stocking densities compared with a lower density, but *S. enteritidis* was isolated from fecal samples at a greater overall frequency from hens in conventional cages than from either group housed in enriched cages.

What this means: Hen stocking density can affect the susceptibility of hens to intestinal colonization by *S. enteritidis.*

<u>Indicator 2:</u> During 2017, ARS will develop an understanding of bacterial, viral, and fungal pathogenicity through a systems biology approach. ARS will utilize this data for pathogen intervention and control, modeling, and providing data for the development of risk assessments by regulatory agencies. ARS will ensure that these technologies can be utilized by regulatory agencies, producers, and/or processors to help assure safe food products.

Biopesticides based on non-toxic (atoxigenic) *Aspergillus flavus* strains have become the most widely used intervention for preventing aflatoxin contamination. However, these biopesticides must be approved by and registered with regulatory authorities, and each target crop and each atoxigenic genotype require additional regulatory action. Thousands of atoxigenic genotypes of *A. flavus* exist with broad adaptation, but regulatory approval for use in commercial products has only been granted for a few genotypes. ARS researchers in Tucson, Arizona, addressed this regulatory issue through direct interactions with regulatory authorities, field and laboratory experimentation, and collaborations with the Arizona Cotton Research and Protection Council, the University of California, the International Institute of Tropical Agriculture, commodity groups, and several national governments.

What this means: This work resulted in new and expanded registrations of biopesticides for preventing aflatoxin contamination, including approval for new target crops (figs and almonds), additional *A. flavus* genotypes, and less restrictive handling requirements. Full registrations for the United States, Senegal, and Burkina Faso were added to existing registrations in the United States, Kenya, and Nigeria.

Fusarium head blight (FHB) affects small grain cereal crops by causing yield reductions and contamination of grain with nivalenol (NIV) or deoxynivalenol (DON), two known trichothecene mycotoxins. These toxins are harmful to human and livestock health because of their ability to block protein synthesis. Plants infected with mycotoxin-producing fungi can detoxify DON by attaching the toxin to a sugar. ARS researchers in Peoria, Illinois, and University of Minnesota collaborators identified a gene from barley which produces a sugar-transfer enzyme that efficiently detoxifies DON and NIV. The gene was introduced into an FHB-susceptible wheat variety, and the resulting wheat that expressed the barley gene was significantly more resistant to both the toxins and to FHB.

What this means: This research represents a critical step toward development of wheat with greater resistance to DON and NIV. It also helps guide transgenic and traditional breeding approaches for increasing resistance to DON in cereal crops and thereby improves food safety and crop production.

Indicator 3: During 2017, ARS will develop innovative methods and advanced technology systems that rapidly and accurately detect, identify, and differentiate the most critical and economically important foodborne bacterial, viral, and protozoan pathogens. ARS will ensure that these technologies can be utilized by regulatory agencies and/or producers to help assure safe food products.

Cold plasma is a non-thermal processing technology that uses reactive gases to inactivate foodborne pathogens. ARS researchers in Wyndmoor, Pennsylvania, found that cold plasma treatment can be an effective tool for reducing or eliminating pathogens on food. Cold plasma treatment for 3 minutes eliminated spoilage yeasts and molds, and reduced *Salmonella* levels by up to 99.95 percent on grape tomatoes packaged in a polyethylene terephthalate commercial clamshell container, without affecting product quality. In apples, a chemical sanitizer combined with cold plasma reduced *Listeria monocytogenes* levels more than 99.99 percent, even in the calyx area. Cold plasma applied to blueberries inactivated two widely used surrogates for human norovirus, Tulane virus and murine norovirus. Cold plasma treatment of Romaine lettuce inhibited *Escherichia coli* O157:H7 levels by 92 percent, *Salmonella* spp. levels by 60 percent, *L. monocytogenes* levels by 90 percent, and Tulane virus levels by 95 percent, regardless of packaging humidity content. Both rigid and flexible conventional plastic packages appear to be suitable for the cold plasma decontamination.

What this means: The results show that with further optimization, cold plasma may be used by food processors as a new method to improve the safety of fresh and fresh-cut fruits and vegetables, including fragile produce such as berries.

Probiotic microorganisms have been extensively studied for their beneficial effects in protecting against allergens, pathogens, and toxins. Botulinum neurotoxins (BoNTs) are some of the most poisonous natural toxins known and are threats to public health and safety. ARS researchers in Albany, California, evaluated the effect of probiotic bacteria on the intestinal binding and absorption of BoNT serotype A. The probiotics *Saccharomyces boulardii, Lactobacillus acidophilus, L. rhamnosus* LGG, and *L. reuteri* blocked BoNT/A intestinal uptake in a dose-dependent manner, while a non-probiotic strain of *Escherichia coli* did not.

What this means: These results provide the first evidence that probiotic treatment can inhibit BoNT/A binding and internalization in intestinal cells and could lead to the development of new therapies for treating BoNT poisoning.

Indicator 4: During 2017, ARS will develop intervention and control strategies that will help to significantly decrease or eliminate pathogens in food animals and their derived products (eggs/milk), seafood, and plant crops (produce/grains/tree nuts) during critical periods of production and processing. ARS will develop and subsequently combine new/innovative processing technologies using the intelligent hurdle concept. ARS will ensure that these technologies can be utilized by producers and/or processors to help assure safe food products.

Fresh produce processors traditionally have used a 1 ppm (part per million) free-chlorine level as the control limit and a re-wash as the corrective action solutions in hazard analysis and critical control points (HACCP) programs. ARS researchers in Beltsville, Maryland, determined that the industry standard control limit for chlorine concentration does not prevent pathogen cross-contamination, and that re-washing contaminated product is an ineffective corrective action. The research clearly documented significant risk factors associated with generally considered safe operating practices. Follow up studies further demonstrated that a minimum of 10 ppm free-chlorine was required to effectively prevent pathogen cross-contamination during washing.

What this means: These recommendations have been adopted by leading processors and incorporated in the interagency and industry taskforce whitepaper entitled, "Guidelines to Validate Control of Cross-Contamination during Washing of Fresh-Cut Leafy Vegetables."

Damage of fruit nuts by navel orangeworm has been associated with increases in *Aspergillus* infection, a risk factor for aflatoxin contamination. ARS researchers in Albany, California, developed and patented a new blend of host plant volatiles that attracts the navel orangeworm to almonds. The efficacy of this blend in attracting both male and female navel orangeworms was demonstrated in orchards and used in monitoring worm infestation and as an aid in pest management. The navel orangeworm blend (U.S. Patent No. 9,655,366) is being developed as a product for commercialization.

What this means: This new technology will help farmers monitor and reduce navel orangeworm infestation in orchards and eliminate aflatoxin contamination.

Indicator 5: During 2017, ARS will develop bioinformatic databases and tools, and predictive user-friendly models to understand pathogen behavior and acquisition of virulence characteristics under various stress conditions. ARS will determine the key risk factors of human pathogens in foods, and evaluate systems interventions for their impact, which will enable regulatory/action agencies to make critical food safety decisions that impact public health.

Mathematical models are frequently used to predict microorganism growth and survival in food throughout the supply chain, and are the foundation of quantitative microbiological risk assessment. Accurate estimation of kinetic parameters is essential to predictive modeling. ARS researchers in Wyndmoor, Pennsylvania, have expanded the USDA IPMP–Global Fit, a one-step kinetic analysis software for predictive modeling. Growth and survival models are included in the new software for direct construction of predictive models that minimize the global errors.

What this means: This new approach to mathematical modeling can significantly improve the accuracy of data analysis and future model development. Researchers and risk modelers around the world can download and use IPMP–Global Fit without charge.

Indicator 6: During 2017, ARS will develop innovative methods and advanced technology systems that rapidly and accurately detect and identify veterinary drugs, chemical residues, heavy metals, persistent organic pollutants, and biological toxins derived from bacteria, fungi, and plants. ARS will evaluate contaminant toxicity and mechanism of action. ARS will provide data which will enable regulatory/action agencies to make critical food safety decisions that impact public health.

Zilpaterol is an FDA-approved beta-agonist feed additive that increases feed efficiency, improves growth rate, and produces lean meat in livestock. Several major U.S. trading partners do not allow the import of meat from animals fed zilpaterol and zilpaterol is illegal to use in some food animal species in the United States. ARS researchers in Fargo, North Dakota, developed a sensitive, selective, inexpensive, and rapid test to determine whether animals have been exposed to zilpaterol. The assay, which is similar to an over-the-counter pregnancy test, can be used on-site with minimal training, and results are ready in about 10 minutes. The accuracy and sensitivity of the assay was verified in tissues and urine from animals exposed to zilpaterol.

What this means: This simple and inexpensive assay could be used to determine accidental, illegal, or intentional zilpaterol exposure.

ARS researchers in Beltsville, Maryland, have developed a new use for Raman spectroscopy called point-scan and line-scan (i.e., Raman chemical imaging) to nondestructively detect chemical contaminants in powdered food materials. Without any special sample preparation, the newest system can analyze a 30-ml sample (2 tablespoons) of dry powder within 10 minutes more quickly and efficiently than conventional Raman instruments that might require 24 hours to analyze the same sample. The system can perform quantitative contaminant detection down to concentrations as low as 50 parts per million of benzoyl peroxide (used for bleaching) in wheat flour or melamine in milk powder, for example.

What this means: This system, which is currently under patent review, will provide a useful screening mechanism to help detect contaminated food products and prevent their distribution and use.

Indicator 7: During 2017, ARS will develop approaches to understand the development, persistence, and transmission of antimicrobial resistant (AMR) genetic elements that result in antimicrobial resistant foodborne pathogens. ARS will develop and validate assays to rapidly detect and assess AMR pathogens. ARS will develop and evaluate alternatives to antibiotics to reduce the development of AMR in foodborne pathogens.

Colistin is an antibiotic classified by the World Health Organization as being of critical importance to human health. In 2015, a gene (mcr-1) for colistin resistance was found that increases the ease and rate at which resistance can spread to different bacteria. In 2016, ARS researchers in Athens, Georgia, found this bacterial gene in the stomach contents of livestock. From more than 2,000 cecal samples, two isolates of *Escherichia coli* were found that carried the mcr-1 gene. Isolates were characterized by whole genome sequencing, resistance profiling, and plasmid mobility studies. The total genomic DNA of the isolates were sequenced, and the U.S. isolates were determined to have descended from isolates found in China. But they were substantially different from each other, so a direct link between them could not be made.

What this means: This was the first detection of the mcr-1 gene in the United States, and at this time, it is unknown how the resistance gene traveled from China to the United States.

Meats produced from animals raised without antibiotics (RWA) are perceived to harbor lower levels of antimicrobial resistance than meats from animals produced with no restrictions on antimicrobial use (conventional). ARS researchers in Clay Center, Nebraska, measured the prevalence and concentrations of antimicrobial resistant bacteria and the levels of 10 antimicrobial resistance genes in ground beef and pork chops from animals raised without antibiotics or by conventional methods. The researchers found that generally the levels of antimicrobial resistance were similar between the meats from animals raised either way.

What this means: These results demonstrate that conventional beef and pork products do not pose a greater risk of exposure to antimicrobial resistance than RWA products.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 1.2

During FY 2018, ARS will:

1. Determine how population systems in animals, plants, or the environment, or any combination of these influence the safety of food. Determine the conditions under which microorganisms exist. Determine how microorganisms may in turn influence the conditions prevailing in the environment. Ensure that these technologies can be utilized by regulatory agencies, producers and/or processors to help assure safe food products.
2. Develop an understanding of bacterial, viral, and fungal pathogenicity through a systems biology approach. Utilize this data for pathogen intervention and control, modeling, and providing data for the development of risk assessments by regulatory agencies. Ensure that these technologies can be utilized by regulatory agencies, producers and/or processor to help assure safe food products.
3. Develop innovative methods and advanced technology systems that rapidly and accurately detect, identify, and differentiate the most critical and economically important foodborne bacterial, viral, and protozoan pathogens.

During FY 2019, ARS will:

1. Determine how population systems in the food continuum influence the safety of the food supply.
2. Develop innovative methods and advanced technology systems that rapidly, accurately and cost effectively detect, identify, and differentiate foodborne pathogens, chemical residues and biological toxins in foods.
3. Develop intervention and control strategies that decrease or eliminate contaminants in the food supply to make it safer for consumers.
4. Develop bioinformatic tools to understand acquisition of virulence characteristics. Develop databases, and predictive models to understand pathogen behavior, and provide data for the development of risk assessments.
5. Develop approaches to understand antimicrobial resistance and evaluate alternatives to antibiotic use.

During FY 2020, ARS will:

1. Determine how population systems in the food continuum influence the safety of the food supply.
2. Develop innovative methods and advanced technology systems that rapidly, accurately and cost effectively detect, identify, and differentiate foodborne pathogens, chemical residues and biological toxins in foods.
3. Develop intervention and control strategies that decrease or eliminate contaminants in the food supply to make it safer for consumers.
4. Develop bioinformatic tools to understand acquisition of virulence characteristics. Develop databases, and predictive models to understand pathogen behavior, and provide data for the development of risk assessments.
5. Develop approaches to understand antimicrobial resistance and evaluate alternatives to antibiotic use.

Ensure that these technologies can be utilized by regulatory agencies and/or producers to help assure safe food products.

4. Develop intervention and control strategies that will help to significantly decrease or eliminate pathogens in food animals and their derived products (eggs/milk), seafood, and plant crops (produce/grains/ tree nuts) during critical periods of production and processing. Develop and subsequently combine new/innovative processing technologies using the intelligent hurdle concept. Ensure that these technologies can be utilized by producers and/or processors to help assure safe food products.
5. Develop bioinformatic databases and tools, and predictive user-friendly models to understand pathogen behavior and acquisition of virulence characteristics under various stress conditions. Determine the key risk factors of human pathogens in foods, and evaluate systems interventions for their impact, which will enable regulatory/action agencies to make critical food safety decisions that impact public health.
6. Develop innovative methods and advanced technology systems that rapidly and accurately detect and identify veterinary drugs, chemical residues, heavy metals, persistent organic pollutants, and biological toxins derived from bacteria, fungi, and plants. Evaluate contaminant toxicity and mechanism of action. Provide data which will enable regulatory/action agencies to make critical food safety decisions that impact public health.
7. Develop approaches to understand the development, persistence, and transmission of antimicrobial resistant (AMR) genetic elements that result in antimicrobial resistant foodborne pathogens. Develop and validate assays to rapidly detect and assess AMR pathogens. Develop and evaluate alternatives to antibiotics to reduce the development of AMR in foodborne pathogens.

Goal 1.3 - Enhance the Economic Viability and Competitiveness of U.S. Agriculture by Maintaining the Quality of Harvested Agricultural Commodities or Otherwise Enhancing their Marketability, Meeting Consumer Needs, Developing Environmentally Friendly and Efficient Processing Concepts, and Expanding Domestic and Global Market Opportunities through the Development of Value-Added Food and Nonfood Technologies and Products, except Energy and Fuels

NATIONAL PROGRAM 306 – QUALITY AND UTILIZATION OF AGRICULTURAL PRODUCTS

This research will increase our knowledge and develop technologies to better measure or enhance the quality of crop and animal products after harvest. Similarly, the marketability and value of commodities can be increased by ensuring that value-added food products (such as fresh-cut or minimally processed produce) retain sensory quality, nutritional value, and are free from food safety hazards. The research in this National Program will also generate new information on health promoting components of foods and assess their effects on important human diseases and obesity, in cooperation with the Human Nutrition National Program (NP 107) and other partners. In addition to food quality and safety, consumers have expressed concern over rising food prices which can be attributed to multiple factors. A significant factor in the cost of food production can be attributed to food waste or rot. Estimates indicate that approximately 27 percent of food produced in the United States is lost as waste among retailers, food service businesses, and consumers. Additional losses occur during food harvesting, storage, and distribution. The magnitude of the loss is even greater when resources spent on growing food such as fuel, water, fertilizer, chemicals, land-use, and human resources are considered. NP 306 research will develop technologies that improve quality, extend product shelf life, reduce waste, and decrease costs.

ARS conducts research on the development of nonfood, nonfuel biobased products from agricultural commodities and byproducts. Interest in biobased products has increased as consumers and governments have sought more environmentally friendly products that provide alternatives to petroleum and which do not contribute to greenhouse gases. Thus, biobased products can reduce our dependency on petroleum and provide a more sustainable technology for the future. Biobased products that were once too expensive to commercialize may now be affordable. There is some public concern that biobased products could contribute to the rising cost of food in the United States. This program seeks opportunities to develop biobased products from agricultural feedstocks that do not compete with food, in cooperation with other ARS national programs and partners. ARS also supports quality and processing research on crop fiber, such as cotton, and from animal hides, such as leather and wool. Stakeholders who produce fibers and hides constitute an important segment of our rural economy. These industries are severely impacted by energy and production costs and have lost market share to foreign competition. Technologies that improve fiber quality, reduce the energy consumption of processing equipment, and develop new products are needed to help the fiber industry to compete in a global market.

PERFORMANCE MEASURE FOR GOAL 1.3

Develop methods and technologies to better define, measure, preserve or enhance quality and improve utilization of food crops, animals and agricultural fibers, as well as non-food, non-fuel biobased products and sustainable technologies/processes.

FY 2017 PERFORMANCE REPORT FOR GOAL 1.3 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will enable commercially-viable post-harvest technologies for non-food biobased products and for value-added non-food processing.

Parthenium argentatumm, commonly known as guayule (gwai'u'li), is a flowering shrub native to the southwestern United States. The plant has been studied for nearly 150 years as a possible source of natural rubber, organic resins, and as a biofuel feedstock. However, the United States tire industry still relies on 100 percent imported natural rubber, which comprises 80 percent of a tire. Developing guayule-rubber for use in modern tires is critical for supplementing the ever-growing need for rubber worldwide, and in particular, for developing a U.S. natural rubber-production industry. With funding from the USDA National Institute for Food and Agriculture (NIFA), ARS led a 5-year collaborative research effort to domesticate and develop a commercial guayule farming system in Maricopa, Arizona, for rubber production, and to refine rubber biotechnology and chemistry for converting the plant into rubber at commercial scale in Albany, California. In collaboration with university partners and rubber and tire industry leaders, ARS produced breakthroughs in guayule rubber processing, stabilization, and performance that allowed passenger tires to be produced with 100 percent guayule rubber. The tires, developed by an industry partner, passed both the specified testing by the U.S. Department of Transportation and the more stringent internal industry testing.

What this means: Seventy-five percent guayule-rubber tires with exceptional wear and performance are available commercially at a price comparable to high performance tires.

Millions of consumers use lighter fluid to light charcoal for cooking, which contributes to the level of volatile organic compounds in the air around residential neighborhoods. ARS scientists in Albany, California, developed a porous charcoal material from plant waste using plant starch to bind biochar powder from walnut and almond hulls into quick-igniting charcoal briquettes that can be easily lit without lighter fluid. The "starter" briquettes can be used to ignite traditional briquettes without the use of lighter fluid.

What this means: This patented technology will help consumers comply with regional air district recommendations to reduce air polluting activities when air alerts are issued.

The process of cleaning cotton after it is harvested currently requires the use of dangerously hot and caustic substances and large amounts of rinse water, and generates large amounts of waste. ARS scientists at New Orleans, Louisiana, developed a combination of plant-based sustainable enzymes that work in combination with ultrasound energy to enhance the cleaning conditions without generating waste. In an industrial setting this ultrasound/enzyme bio-cleaning process was applied to cotton fabrics without the need for expensive sound-attenuating enclosures or for hearing protection of the workers. This advance also comes with a significant 20 percent reduction in cost and alleviates the health concerns associated with using caustic chemicals. A new system of rollers was also designed, manufactured, and tested that allows the fabric to be continuously fed into the ultrasonic cleaning system.

What this means: The ability to continuously feed fabric is a significant improvement over the current caustic boiling and batch-dipping system and is in the process of large-scale commercialization.

Indicator 2: During 2017, ARS will develop new or improved methods to measure, predict, enhance, or reduce impacts to food marketability, nutritional quality, new bioactives and functional foods, and/or food processing technologies.

Packaging is a critical part of modern food technology because of the increased consumer interest in processed, pre-packaged foods. The challenge for the food industry, however, is to develop packaging that has the correct utility and is consumer and environmental friendly. Most foods are wrapped in petroleum-based plastic packaging, which is not only poor at preventing spoilage, but is also non-biodegradable and creates waste when removed. Recently, ARS researchers in Wyndmoor, Pennsylvania, developed a milk-based edible film from casein – a milk protein – that can be used to wrap fresh foods to preserve quality; create pouches that dissolve in hot water to release instant soup or coffee; or coat breakfast cereals to keep them crispy in milk, thus replacing the sugarcoating that serves the same purpose. The technique of electrospinning was used to produce very fine porous mats of casein fibers called nanofibers which have small diameters but large surface areas. Due to their large surface areas, these fibers can be formed into edible films that have the potential to introduce intense colors, flavors, or textures within or on foods, and can be used to deliver controlled amounts of nutrients such as vitamins, minerals, or therapeutics from foods.

What this means: This edible milk-protein film is being tested by Lipton Soup Co. for potential use as consumer and environmentally friendly packaging for its various food products.

Currently the hot-air drying of fruit and vegetables is an important U.S. industry worth $50 billion annually, but it is also the third largest industrial energy user in California. To substantially reduce energy usage and improve dried produce appearance and flavor, ARS scientists in Albany, California, developed a two-stage, infrared-blanching and hot-air drying system. Crispy and healthy fruit and vegetable snacks were produced at a commercial scale through the support of the California Energy Commission. The project demonstrated the novel drying system technology in producing healthy crispy snacks from carrots, kale, bell peppers, squashes, pears, and apples. This demonstration showed the benefits of the new technology, both in a 75 percent energy savings and a reduction in environmental pollution, while providing new healthy snacks with desirable texture and flavor at an affordable cost.

What this means: This technology was recently licensed by a private company to produce healthy snacks while saving energy and water.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 1.3

Note that the research undertaken in Goal 2.3 in 2017 and earlier will be combined into a revised Goal 1.3 starting in 2018. The revised goal statement will be “Improve Postharvest Quality and Develop New Uses of Agricultural Products.” The following indicators reflect that change.

During FY 2018, ARS will:

1. Develop new or improved methods to measure, predict, enhance or reduce impacts to food marketability, nutritional quality, develop new uses, and/or food processing technologies.
2. Enable commercially-viable post-harvest technologies for non-food biobased products, for new uses and for value-added processing.
3. Enable technologies that can reduce business risks, increase the production of new biofuels and the value of co-products, and/or expand the number of revenue streams for existing biorefineries.

During FY 2019, ARS will:

1. Develop new or improved methods to measure, predict, enhance or reduce impacts to food marketability, nutritional quality, develop new uses, and/or food processing technologies.
2. Enable commercially-viable post-harvest technologies for non-food biobased products, for new uses and for value-added processing.
3. Enable technologies that can reduce business risks, increase the production of new biofuels and the value of co-products, and/or expand the number of revenue streams for existing biorefineries.

During FY 2020, ARS will:

1. Develop new or improved methods to measure, predict, enhance or reduce impacts to food marketability, nutritional quality, develop new uses, and/or food processing technologies.
2. Enable commercially-viable post-harvest technologies for non-food biobased products, for new uses and for value-added processing.
3. Enable technologies that can reduce business risks, increase the production of new biofuels and the value of co-products, and/or expand the number of revenue streams for existing biorefineries.

GOAL AREA 2: NATURAL RESOURCES AND SUSTAINABLE AGRICULTURAL SYSTEMS

We conduct research that *explains* the nature and function of agricultural systems and their physical, chemical, and biological components. With that explanatory power, we develop abilities to *predict* how agricultural systems may respond to different environments or management scenarios. Once we can make predictions with confidence, we turn that knowledge into *decision support* tools and methods for:

- Improving the efficiency and effectiveness of management practices for agricultural systems and working lands to enhance ecosystem goods and services, including the sustainable production of agricultural commodities;
- Managing soil, water, air, and biological resources for society's benefits, including reductions in environmental impact, under different climatic regimes and environmental conditions;
- Providing agricultural products and co-products as renewable, bio-based alternatives to petroleum as inputs to manufacturing and generating energy;
- Developing new, valuable, environmentally sound uses for agricultural and industrial byproducts.

Major priorities for ARS research on interactions among land, water, atmosphere, and diverse biological communities include remediation and use of degraded water for production of a wide range of crops; protection and enhancement of ecosystem goods and services arising from our natural resources; adaptation of agricultural production systems to climate change, and mitigation of agricultural greenhouse gas emissions; development of diverse energy crops and agronomic practices for efficient and sustainable production, optimized for different geographic regions and climatic conditions throughout the U.S.; identification of safe uses of agricultural wastes and byproducts in generating energy/fuel and value-added biochemical products and fertilizers; creation and evaluation of conservation practices and land management decision-support tools arising from ARS' long-term agricultural research conducted in the agency's unique, critical infrastructure of instrumented watersheds and rangelands; development of widely accessible databases to support analyses of agriculture, land management, and the environment; and creation of a broad-based data and information access portal at the National Agricultural Library to enable life-cycle analyses and development/validation of sustainability indices for agricultural production and delivery systems.

Goal 2.1 – Integrated, Effective, and Safe Water Resource Management

NATIONAL PROGRAM 211 – WATER AVAILABILITY AND WATERSHED MANAGEMENT

Fresh water is essential to maintaining both agricultural and industrial production, ecosystem integrity, and human health. As the nation was established and expanded, it flourished in part because of its abundant and readily available water and other natural resources. As the 21st century unfolds, agriculture faces new and intensifying water challenges—increasing demands for water from our cities, farms, and aquatic ecosystems; increasing reliance on irrigated agriculture for stable crop and animal production and farm income; and changing water supplies due to groundwater depletion in some areas, climate variability and change, and the need to tap alternative water sources. These challenges are not insurmountable, and agricultural lands can play an important role in meeting them. Advances in agricultural water management can provide important and unique contributions to the complex problem of water management at regional and national scales. As new and emerging technologies widen the range of options for future water management, science can develop and provide the tools needed by managers and planners to accurately predict the outcomes of proposed water management decisions at farm to national scales. The factual basis for decision-making includes an understanding of these new technologies, their effectiveness as well as potential unintended consequences, and a strategy for getting water users and agencies to adopt the technologies determined to be most effective. Thus the Nation has the opportunity to apply and use science and technology to protect, sustain, enhance, and manage our water resources, improving human and ecological health while continuing to build a strong and growing economy.

PERFORMANCE MEASURE FOR GOAL 2.1

Develop technology and practices to promote improvement of integrated, effective, and safe water resource management.

FY 2017 PERFORMANCE REPORT FOR GOAL 2.1 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will develop new or improved guidelines, technologies, and/or knowledge to increase the effectiveness of agricultural water management.

Accurately measuring crop water use (evapotranspiration or ET) at appropriate temporal and spatial scales is important for effectively managing agricultural water use. To address this need, ARS scientists in Beltsville, Maryland, developed and distributed a novel ET mapping toolkit that combines remote sensing data from a range of satellite platforms into daily crop water use estimates at an unprecedented 30-meter spatial resolution.

What this means: Because of its significant resolution advantages, the toolkit has already been used to address many water resource issues in agriculture: studying groundwater depletion via irrigation in Central Wisconsin; assessing the impact of expanding agricultural drainage on regional hydrology in the Corn Belt; improving water use in managed forest plantations; calibrating hydrologic/water quality models for the Chesapeake Bay Watershed; making irrigation management decision in vineyards; assessing consumption for the U.S. Water Census and California's new Sustainable Groundwater Management Act; and delivering drought and water information for the Near-East North African region. The toolkit will also be used to generate ET and water stress products for NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) mission. Using this ET mapping tool in these projects has greatly expanded monitoring and has optimized water use and availability across a broad range of agricultural systems.

While flooded rice systems contribute to global greenhouse gas (GHG) emissions, intermittent rice flooding (also called alternate wetting and drying, or AWD) may significantly reduce GHG emissions and irrigation water use. To learn more about the possible benefits of AWD, ARS scientists in Jonesboro, Arkansas, measured water and carbon dioxide emissions from commercial U.S. rice fields and demonstrated that crop growth stages and production practices directly affect emissions from these systems. Other studies identified how nitrogen fertilizer application rates affect nitrous oxide and methane emissions (both critical GHGs) and helped confirmed how much nitrogen fertilizers contribute to agricultural nitrous oxide and methane emissions. Another study found intermittent flooding reduced irrigation water use from 20 to 70 percent compared to conventional (i.e., continuous) flooding, while rice yields remained largely unchanged.

What this means: These studies suggest that (1) using AWD may help significantly reduce water use in commercial U.S. rice production and help producers maintain yields even during droughts that are occurring more frequently; and (2) irrigation management is a key component for mitigating GHG emissions in commercial rice production.

Indicator 2: During 2017, ARS will develop new or improved guidelines, technologies, and/or knowledge to reduce erosion and sedimentation from agricultural lands and/or improve water quality.

Streamside vegetation buffers are a proven practice for removing nitrate from both overland flow and shallow groundwater, thus reducing nitrate entering surface waters. But in landscapes with tile pipe drainage, most of the subsurface flow travels from farm fields through tile pipes, leaving little opportunity for this nitrate removal process. ARS scientists in Ames, Iowa, and university cooperators showed that re-routing a fraction of field tile drainage through riparian buffers can remove hundreds of pounds of nitrate before it enters nearby surface waters each year.

What this means: This buffer system has been adopted by the USDA Natural Resources Conservation Service (NRCS) as Conservation Management Practice Standard #604 and is now eligible for Environmental Quality Incentives Program (EQIP) funding across the Midwest. Research shows the practice could be installed along thousands of miles of rivers in Iowa alone and potentially remove millions of pounds of nitrate from U.S. surface waters.

Many U.S. Midwest corn and soybean fields have subsurface drainage systems facilitating the transport of excess field nitrogen that eventually reaches the Gulf of Mexico and contributes to hypoxic conditions. Projected increases in crop production and fertilizer nitrogen use increases the need to manage cropping systems to maximize yield and minimize nitrogen loss. Scientists from ARS laboratories in Ames, Iowa, and Fort Collins, Colorado, and cooperators in Müncheberg, Germany, added drain flow simulations to the HERMES agricultural system model, which describes plant growth and water and nitrogen dynamics in the soil-plant system. The modified HERMES model was then tested using 4 years of data from central Iowa fields in corn-soybean rotation, with winter rye as a cover crop and without winter rye. The modified model accurately simulated nitrogen loss to subsurface drainage under both cover crops and winter rye, and the simulations agreed with field data showing that winter rye cover crops substantially reduced nitrogen loss to drainage.

What this means: The use of this modified model will help improve agricultural management and reduce nitrogen transport to streams and rivers.

Indicator 3: During 2017, ARS will develop new or improved knowledge, tools, technologies, guidelines, and/or conservation practices to better protect water resources, improve the overall effectiveness of USDA conservation programs, and/or improve watershed management and ecosystem services in agricultural landscapes.

Irrigation reservoirs store surface water supplies that can be used for irrigation in place of groundwater, but reservoir levees are highly susceptible to erosion by wind-driven waves. The condition and characteristics of levees around 148 irrigation reservoirs in Arkansas, such as presence of block-failures and amount of vegetation, were recorded by the NRCS. ARS researchers in Oxford, Mississippi, then conducted detailed data analyses to find patterns in levee characteristics associated with damaged levees and loss of levee top-width. They determined that the most important factor in levee erosion was maximum fetch length, which is the distance across the reservoir in the direction of the prevailing wind.

What this means: Farmers and NRCS field personnel can use these results in designing or modifying levees to increase their resilience to erosion, which enhances the appeal and value of using these reservoirs in irrigated production systems and helps protect groundwater resources.

Filter treatment systems containing synthetic goethite (iron oxyhydroxide) could be a viable means of capturing phosphate and reducing nutrients in agricultural drainage, but goethite can be costly unless it can be regenerated for continual use. ARS scientists in Columbus, Ohio, conducted laboratory and field drainage phosphate removal tests on synthetic goethite, and afterwards regenerated the same material using a sodium hydroxide flush. Laboratory treatment tests showed that both the original and regenerated goethite removed more than 98 percent of the phosphate in agricultural drainage waters. Field agricultural drainage water treatment tests showed that the original goethite removed 75 percent of the phosphate, while the regenerated synthetic goethite removed 34 percent. These results suggest that in field settings, regenerating synthetic goethite will probably require a two-step procedure that uses a diluted acid wash to remove calcium phosphate precipitates followed by a sodium hydroxide flush to release any remaining adsorbed phosphate.

What this means: Using refined regeneration process filter treatment systems containing synthetic goethite could be a cost effective phosphate removal treatment for drainage water.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 2.1

During FY 2018, ARS will:

1. Develop new or improved guidelines, technologies, and/or knowledge to increase the effectiveness of agricultural water management.
2. Develop new or improved guidelines, technologies, and/or knowledge to reduce erosion and sedimentation from agricultural lands and/or improve water quality.
3. Develop new or improved knowledge, tools, technologies, guidelines, and/or conservation practices to better protect water resources, improve the overall effectiveness of USDA conservation programs, and/or improve watershed management and ecosystem services in agricultural landscapes.

During FY 2019, ARS will:

1. Develop new or improved guidelines, technologies, and/or knowledge to increase the effectiveness of agricultural water management.
2. Develop new or improved guidelines, technologies, and/or knowledge to reduce erosion and sedimentation from agricultural lands and/or improve water quality.
3. Develop new or improved knowledge, tools, technologies, guidelines, and/or conservation practices to better protect water resources, improve the overall effectiveness of USDA conservation programs, and/or improve watershed management and ecosystem services in agricultural landscapes.

During FY 2020, ARS will:

1. Develop new or improved guidelines, tools, technologies, and/or knowledge to increase the effectiveness of agricultural water management and improve drought resilience.
2. Develop new or improved guidelines, technologies, and/or knowledge to reduce erosion and sedimentation from agricultural lands and/or improve water quality.
3. Develop new or improved knowledge, tools, technologies, guidelines, and/or conservation practices to better protect water resources, improve the overall effectiveness of USDA conservation programs, and/or improve watershed management and ecosystem services in agricultural landscapes.

Goal 2.2 – Improve Quality of Atmosphere and Soil Resources, Understand Effects of Climate Change

NATIONAL PROGRAM 212 – SOILS AND AIR

Agricultural systems function within the soil-atmosphere continuum. Mass and energy exchange processes occur within this continuum and agriculture can significantly affect the processes. Emissions from agriculture to the atmosphere affect air quality and increase atmospheric greenhouse gas (GHG) concentrations. While GHG emissions are largely a result of the natural cycling of carbon (C) and nitrogen (N), these emissions also contribute to climate change.

A changing climate impacts agriculture, range and pasture systems, and soils through alterations of precipitation and temperature patterns. Increased atmospheric carbon dioxide (CO_2) concentration has an enhanced fertilization effect on plants, particularly weeds. Combining these impacts of changing climate can alter habitats, thus changing the distribution of pathogens, weeds, and invasive species, resulting in increased threats to agricultural production and increasing the cost of production. The impacts of climate change clearly create challenges to agriculture and soil, water, and air resources, and yet may also offer new opportunities for agricultural production and enhancement of soil quality.

Soils are a crucial boundary resource between agriculture and the atmosphere. Soils in agricultural systems must be managed to meet rising global demands for food, feed, fiber, fuel, and ecosystem services while maintaining soil productivity and limiting undesirable interactions between soils and the atmosphere. Enhancement of soil productivity is a focus of ARS research and together with crop improvement research offers promise for meeting future global agricultural demands.

The variability of the atmosphere, soils, and plants, and the complexity of interactions among these systems require collaborations by ARS scientists conducting NP 212 research. Formal and informal Cross Location Research (CLR) projects including the Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet), the Resilient Economical Agricultural Practices project (REAP; formerly called the Renewable Energy Assessment Project), the Long-Term Agroecosystem Research (LTAR) Network, and field campaigns focused on air quality are successful examples. Synthesis and integration of information, including sources outside NP 212 research projects, increases the utility and impact of ARS research for producers, land managers, and policy-makers. Efficient assimilation of data from NP 212 projects into existing and future collaborative data bases enhances synthesis and integration analyses and expands research opportunities.

PERFORMANCE MEASURE FOR GOAL 2.2

Improve quality of atmosphere and soil resources; understand effects of climate change through development of knowledge and technologies.

Indicator 1: During 2017, ARS will develop management practices and decision tools to improve quality and resilience of agricultural soils, protect air quality, improve production amidst climate variability, and reduce net GHG emissions.

Results from plot trials in the inland Pacific Northwest suggested that no-tillage production, which helps conserve soil resources, provides sufficient soil water for autumn planting of winter wheat. ARS researchers at Pendleton, Oregon, expanded upon these findings to conduct field scale experiments comparing soil water content and winter wheat yields between traditional inversion tillage and current no-tillage technology in two arid upland drainages. They found winter wheat yields were similar between no-tillage and conventional tillage, and that no-tillage fields had significantly more plant-available water in topsoil before planting.

What this means: These results confirmed that improvements in herbicides, equipment, and wheat varieties in the last 30 years have resolved earlier plant-water problems in no-tillage practices and demonstrate that no-tillage production is capable of meeting or exceeding crop productivity using traditional inversion tillage. By reducing the tillage operations, this finding will save money for inland northwest wheat producers. This work will also increase adoption and development of no-tillage cropping systems in the inland Pacific Northwest.

Nitrous oxide (N_2O) emissions significantly contribute to global warming and emissions have increased worldwide over the past few decades. N_2O losses from fertilizer are considered to be agriculture's overall largest contributor to global warming; in addition, these losses are concerning because nitrogen that would otherwise be available for plants is lost via the emissions. ARS researchers at Auburn, Alabama, have identified and developed microbial inoculants that reduce N_2O losses from nitrogen fertilizers and improve plant production and plant nutrient efficiency.

What this means: These microbial inoculants have been patented and are available to producers for reducing N_2O emissions and providing these other beneficial outcomes in production agriculture.

Indicator 2: During 2017, ARS will manage odor and reduce atmospheric emissions from animal production facilities, including increased efficiency of recovery and utilization of manure nutrients, biogas, and other byproducts.

New processes and technologies to recover and reuse nitrogen and phosphorus from animal wastes will help conserve valuable crop nutrient resources and mitigate their release into the environment. ARS researchers in Florence, South Carolina, developed a new technology that separates and recovers ammonia and phosphorus from liquid effluents and filed a U.S. patent application for this process in 2016 (USDA Docket 83.15). The developed technology can recover 98 percent of the nitrogen, and when enhanced, the technology was able to reduce costs by 70 percent. ARS scientists combined the nitrogen recovery process with a novel phosphorus recovery process, and the combined process produced phosphorus bio-minerals that were similar to the very-high phosphate grade commercial fertilizers favored by the fertilizer industry. This process enabled 100 percent phosphorus recovery efficiencies.

What this means: This technology has a number of wide ranging applications, including treating anaerobic digester effluents arising from swine operations, dairies operations, and even municipal waste water systems. The potential value of implementing this nutrient recovery system in dairy farms alone is about $1.3 billion. This technology will dramatically support livestock producers, municipalities, industrialists, extension practitioners, and other scientists interested in manure nutrient recovery technologies.

One environmental problem associated with the poultry industry is the ammonia emitted from the poultry houses, as these emissions can pollute air and water. ARS scientists at Fayetteville, Arkansas, developed the ARS Air Scrubber, which captures ammonia and dust emitted from poultry houses. Researchers found tall fescue plots fertilized with nitrogen captured from these emissions had yields equal to or greater than yields from fescue that received the same levels of nitrogen from commercial ammonium nitrate fertilizer.

What this means: Over 100 million pounds of ammonia are emitted each year from poultry houses in Arkansas alone; capturing this nitrogen and using it as fertilizer could reduce costs associated with acquiring nitrogen fertilizers and greatly reduce the environmental impact from ammonia emissions.

Livestock production is the main source of ammonia (NH3) in agricultural environments, and limiting or changing the nitrogen fed to the livestock may help reduce NH3 emissions. ARS scientists in Ames, Iowa, found that replacing just 1 percent of the crude protein (CP) in swine diets with amino acid supplements reduced swine NH3 emissions by 9.6 percent and odor emissions by 5 percent. Furthermore, emissions continued to decrease in this manner with each percent change in CP and amino acid supplement change. The source of protein in the diet also had an influence on emissions of both ammonia and odor.

What this means: These results indicate that livestock diet reformulations with crystalline amino acids might help lower NH3 emissions and reduce the environmental footprint of swine facilities.

Indicator 3: During 2017, ARS will develop management practices that promote soil biological components and improve agricultural system productivity resulting in validated and quantitative positive impacts on agro-ecosystem function.

A main goal of ARS research is to increase crop yields while reducing the use of water, fertilizers, pesticides, and other production inputs. Soil microorganisms such as arbuscular mycorrhizal [AM] fungi naturally form symbiotic relationships with plant roots and help roots absorb needed plant nutrients from the soil. ARS researchers at Wyndmoor, Pennsylvania, found that eggplant yields in crops inoculated with AM fungi increased from 6 to 18 percent. The AM inoculants were produced on-farm at a cost of less than a penny per plant.

What this means: This result demonstrates the great potential for the use of AM fungi to increase the yield of vegetables without increased inputs.

Soil organic carbon (SOC) must be maintained or increased to ensure crop productivity and soil health. But SOC levels in the Pacific Northwest dryland production region has greatly declined in the past few decades because of intensive tillage, low biomass inputs, fallow production, and straw burning. In the early 1980s, ARS researchers in Pendleton, Oregon, measured SOC in crop fields to a depth of 60 inches, and repeated their measurements in the early 2000s. They found that cropping with winter wheat and peas increased deep SOC the most, while enrolling fields in the Conservation Reserve Program and cropping with winter wheat and reduced tillage also increased deep SOC.

What this means: These results can be used to encourage producers to plant deep-rooted legumes such as peas as rotation crops, and to reduce the use of tillage and fallow for sustainable wheat production.

Indicator 4: During 2017, ARS will reduce the abundance, movement, and environmental impact of pathogens in manure and Pharmaceutically Active Compounds (PACs), and assess the presence, distribution, and impact of antibiotic resistant bacteria and antibiotic resistance genes in manures, soils, and surrounding environments.

Managing the persistence of foodborne pathogens such as *Salmonella* is a complex challenge in the food animal production environment. Cattle are asymptomatic carriers of *Salmonella* and continuously shed these and other bacteria into the environment, which may result in hide contamination that can subsequently lead to carcass contamination and create a significant food safety risk. ARS scientists in Clay Center, Nebraska, worked with commercial scientists and an ARS scientist in Bowling Green, Kentucky, on a study to evaluate an automated detection assay for the detection and quantification of *Salmonella* from rectoanal mucosal swabs (RAMS) collected from beef cattle. When tested on samples that had been incubated for 8 hours ("enriched"), this method was 100 percent sensitive and specific for *Salmonella* detection. When used on RAMS samples immediately (without enrichment,) it showed 67 percent sensitivity and 100 percent specificity, compared to a traditional microbial growth culture method.

What this means: This automated method provided a rapid and reliable procedure for detecting and measuring Salmonella in feedlot cattle. Results are available 3 days earlier than in other tests, and it also reduces labor and supply costs, and will potentially improve the safety of beef supply through earlier pathogen detection.

While dairy farmers use anaerobic digestion of manure to produce energy, the process can also destroy zoonotic pathogens that infect livestock and humans. On large dairy farms, anaerobic digestion is commonly paired with manure separation where the separated solids can be composted and used as cattle bedding. The extent of pathogen destruction in digesters is not well-characterized, and pathogen distribution of separated manure components is not known. It is important to determine these pathogen levels, as the solid fraction may be later used for bedding, and the liquid fractions may be later applied to land as fertilizer. ARS researchers in Marshfield, Wisconsin, studied seven manure digesters with separators and determined that pathogen destruction is suboptimal and highly variable among farms and seasons. Surviving pathogens may end up in the liquid fraction of separated manure, and could result in human exposure during land-application.

What this means: This research shows livestock producers need to optimize the performance of their digesters to maximize public health benefits. Fortunately, the optimization efforts will likely also improve biogas yields during digestion, which in turn improves the economic viability of digesters.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 2.2

Note that the research undertaken in Goal 2.4 in 2016 and earlier will be combined into a revised Goal 2.2 starting in 2017. The revised goal statement will be "Improve Air and Soil Quality and the Efficient Utilization of Byproducts for Enhanced Sustainability." The following indicators reflect that change.

During FY 2018, ARS will:

1. Develop management practices and decision tools to improve quality and resilience of agricultural soils, protect air quality, improve production amidst climate variability, and reduce net GHG emissions.
2. Manage odor and reduce atmospheric emissions from animal production facilities, including increased efficiency of recovery and utilization of manure nutrients, biogas and other byproducts.
3. Develop management practices that promote soil biological components and improve agricultural system productivity resulting in validated and quantitative positive impacts on agro-ecosystem function.
4. Reduce the abundance, movement and environmental impact of pathogens in manure and Pharmaceutically Active Compounds (PACs), and assess the presence, distribution, and impact of antibiotic resistant bacteria and antibiotic resistance genes in manures, soils and surrounding environments.

During FY 2019, ARS will:

1. Develop management practices and decision tools to improve quality and resilience of agricultural soils, protect air quality, improve production amidst climate variability, and reduce net GHG emissions.
2. Manage odor and reduce atmospheric emissions from animal production facilities, including increased efficiency of recovery and utilization of manure nutrients, biogas and other byproducts.
3. Develop management practices that promote soil biological components and improve agricultural system productivity resulting in validated and quantitative positive impacts on agro-ecosystem function.
4. Reduce the abundance, movement and environmental impact of pathogens in manure and Pharmaceutically Active Compounds (PACs), and assess the presence, distribution, and impact of antibiotic resistant bacteria and antibiotic resistance genes in manures, soils and surrounding environments.

During FY 2020, ARS will:

1. Develop management practices and decision tools to improve quality and resilience of agricultural soils, protect air quality, improve production amidst climate variability, and reduce net GHG emissions.
2. Manage odor and reduce atmospheric emissions from animal production facilities, including increased efficiency of recovery and utilization of manure nutrients, biogas and other byproducts.
3. Develop management practices that promote soil biological components and improve agricultural system productivity resulting in validated and quantitative positive impacts on agro-ecosystem function.
4. Reduce the abundance, movement and environmental impact of pathogens in manure and Pharmaceutically Active Compounds (PACs), and assess the presence, distribution, and impact of antibiotic resistant bacteria and antibiotic resistance genes in manures, soils and surrounding environments.

Goal 2.3 – Enable New Biorefining Technologies to Support an Economically Robust Biorefining Industry

NATIONAL PROGRAM 213 – BIOREFINING

The ARS bioenergy program develops technologies to enable sustainable commercial production of biofuels by the agricultural sector in ways that enhance our natural resources without disrupting existing food, feed, and fiber markets. Research will optimize both the production of plant feedstocks and the biorefining of agricultural materials to bioenergy and value-added coproducts. This research will strengthen rural economies, provide supplies of renewable transportation fuel, enhance energy security, and improve the U.S. balance of trade, while diversifying rural economies and employment with new biobased technologies and commercial coproducts.

The growth and long-term viability of bioenergy production in the Nation is impeded by a number of technical and commercial barriers. ARS leverages its unique strengths and capabilities to pursue technical barriers that can be overcome by ARS resources.

In addition to tackling specific technical barriers and leveraging ARS core competencies, ARS bioenergy research is consistent with relevant non-technical considerations associated with public policy, general resource constraints, and overall practices/trends within the bioenergy industry.

PERFORMANCE MEASURE FOR GOAL 2.3

Develop technologies to enable sustainable commercial production of bioenergy feedstocks and other biofuels.

FY 2017 PERFORMANCE REPORT FOR GOAL 2.3 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will enable technologies that can reduce business risks, increase the value of co-products, and/or expand the number of revenue streams for existing biorefineries.

An established field of 'Liberty' switchgrass, an ARS cultivar, was grown on marginal, non-food cropping land in central Wisconsin in 2014 and 2015 and processed into bioethanol, yielding 3,510 to 4,960 liters per hectare. By comparison, corn grown on nearby high-quality food cropping land (yielding an above-average 200 bushels/acre) produced 5,300 liters per hectare of bioethanol. 'Liberty', the newest ARS cultivar bred for biomass production of bioethanol, has far exceeded the yield of other popular switchgrass cultivars (Summer and Kanlow). This is the first study of field-to-fermentation integration and the first study using 'Liberty' switchgrass.

What this means: These findings help establish 'Liberty' switchgrass as a viable industrial crop, a critical need in lowering the risk for U.S. farmers and ethanol processors considering the production of advanced biofuels in the northern United States.

Crop residues such as cornstalks, straw, and sugarcane bagasse are abundant feedstocks that can supplement the world's fuel and chemical needs through biorefining. Biorefining requires a host of different enzymes to convert plant materials into commercially viable by-products. ARS scientists in Albany, California, developed a way for enzymes to work more efficiently by mounting up to 18 different enzymes in a ladder structure called a Rosettazyme. To release sugars from the feedstock, enzymes were linked to each other, then a different combination of enzymes was linked on a different enzyme-ladder to convert the sugars into acid compounds. Those compounds are the building blocks in the green manufacture of nylon plastics.

What this means: Use of the Rosettazyme ladder system resulted in 71 percent greater efficiency than when using the same nonlinked enzymes in biorefining systems.

Indicator 2: During 2017, ARS will enable technologies for the production of new biofuels which are compatible with the Nation's existing fuel distribution infrastructure.

Yarrowia yeast strains are critical for the bioconversion of lignocellulosic biomass into diverse lipids for potential conversion to biodiesel; for food and healthcare applications; for organic acids; and recently, as protein-rich feed supplements for the animal and aquaculture industries. ARS scientists in Peoria, Illinois, screened 45 types of *Yarrowia* from the ARS culture collection. Those different strains of *Yarrowia* were evaluated in a harsh, dilute-acid, switchgrass media for growth robustness, and breadth of sugars and lipids produced. The top-producing strain accumulated more than three times the quantity of lipids than the strain that is commonly used in commercial bioconversion systems.

What this means: This more robust strain offers a new and better option for conversion of biomass into lipid biofuels and other bioproducts. This reduces the risk faced by bioconversion companies.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 2.3

Note: The research for Goal 2.3 will be combined into Goal 1.3 starting with Fiscal Year 2018.

Goal 2.4 – Effectively and Safely Manage and Use Manure and Other Agricultural and Industrial Byproducts in Ways that Maximize their Potential Benefits while Protecting the Environment and Human and Animal Health

NATIONAL PROGRAM 214 – AGRICULTURAL AND INDUSTRIAL BYPRODUCTS

Improvements are needed in animal feeding and management regimens in order to increase the proportion of dietary nutrients retained in the animal or animal products while decreasing the quantity of dietary nutrients excreted and lost to the environment. Basic research is needed to evaluate the fate and transport of manure nutrients in the major soil-crop systems common to animal agriculture. This is the foundation for developing Best Management Practices (BMP). Application methods are needed that can improve nutrient use efficiency and incorporate manure to conserve N while maintaining adequate crop residue to protect the soil from erosion and runoff. These practices, and their associated nutrient management plans, must be based on sound understanding of the fate and transport of specific nutrients for major soils, hydrologic conditions, and cropping systems.

Information is needed on pathogen inactivation and die-off as well as their potential for regrowth as functions of environmental conditions (e.g., temperature, moisture, etc.) during all stages of waste management. Technologically sound methods are needed for utilizing byproducts that will be characterized as beneficial and can result in products that are commercially sustainable. This includes blending, composting, and amending byproducts as well as developing land application and management techniques that will improve soil, water, and air quality in addition to improved plant growth. In addition, improved formulations of agriculture byproducts feedstock for use in industrial as well as agricultural applications are needed.

PERFORMANCE MEASURE FOR GOAL 2.4

Effectively and safely manage and use manure and other agricultural and industrial byproducts in ways that maximize their potential benefits while protecting the environment and human and animal health.

FY 2017 PERFORMANCE REPORT FOR GOAL 2.4 - ACCOMPLISHMENTS

Note: Starting in Fiscal Year 2017, the research for Goal 2.4 was combined into Goal 2.2.

Goal 2.5 - Develop and Transfer Economically Viable and Environmentally Sustainable Production and Conservation Practices, Technologies, Plant Materials and Integrated Management Strategies, Based on Fundamental Knowledge of Ecological Processes, that Conserve and Enhance the Nation's Diverse Natural Resources Found on its Range, Pasture, Hay, and Turf Lands

NATIONAL PROGRAM 215 - RANGELAND, PASTURE & FORAGES

This program develops and integrates improved management practices, germplasm, and land-use strategies to optimize productivity, economic viability, and environmental enhancement in managing vegetation, livestock, and natural resources on private and public grass and forage lands. Research activities include: enhancing conservation and restoration of ecosystems and agroecosystems through improvements based on the application of ecological principles; improving management of fire, invasive weeds, grazing, climate change, and other agents of change; developing grazing-based livestock systems that reduce risk and increase profitability in existing and emerging markets; developing improved grass and forage legume germplasm for livestock, conservation, turf, and bioenergy and bioproduct systems; improving the sustainability of turf management; and improving decision-support systems, including improving inventory, monitoring, and assessment tools.

PERFORMANCE MEASURE FOR GOAL 2.5

Develop and transfer economically viable and environmentally sustainable production and conservation practices, technologies, plant materials, and integrated management strategies based on fundamental knowledge of ecological processes that conserve and enhance the Nation's diverse natural resources found on its range, pasture, hay, and turf lands.

FY 2017 PERFORMANCE REPORT FOR GOAL 2.5 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will provide improved germplasm and cultivars that can be released for pasture, harvested forages, turf, biofuels, rangeland restoration, and conservation.

Plant cell walls in crops are an abundant source of carbohydrates for livestock and biofuel production, but their use is currently limited because some portion of the carbohydrate is enmeshed in a vital structural component known as lignin. ARS researchers at Madison, Wisconsin, are testing ways to modify lignin that would make these cell wall carbohydrates more accessible and in one study created cell walls that did not contain typical lignin components. Livestock and biofuel processing systems were able to digest up to 30 percent more of the carbohydrates in cell walls that contained these modified lignans.

What this means: These results suggest some of these modified lignin components would be promising genetic engineering targets for modifying lignin in forage and biomass crops, which could increase their utility as livestock feed and biofeedstock.

ARS researchers in Tifton, Georgia, recently released Coastcross II (CC II), a new type of forage bermudagrass. CC II has several advantages over Tifton 85 and other bermudagrass cultivars. It has a smaller stem diameter, which allows hay producers to dry and bale CC II slightly sooner than Tifton 85, and provides the finer-stemmed forage horse farmers prefer for their livestock. It has a greater tolerance to bermudagrass stem maggot (BSM), which ARS researchers determined is now present in all areas of the Southeast where bermudagrass is grown for pasture or hay. In Georgia, the incidence and damage from BSM has increased over the past 3 years and can reduce yields by over 50 percent, but yield decreases in CC II were significantly lower than for all other types of bermudagrass in the September harvest, including Tifton 85.

What this means: CC II offers an alternative forage bermudagrass and has already been adopted by numerous hay producers in the southeast United States.

Indicator 2: During 2017, ARS will provide forage, pasture, and rangeland management technologies and strategies that reduce inputs while improving livestock performance and sustaining the environment.

After wildfires on western U.S. rangelands, natural resource agencies often prohibit grazing from 1 to 3 years, and ranchers who need to rent other pasture for their grazing livestock can incur annual costs exceeding $54 million. ARS scientists in Miles City, Montana, in cooperation with the USDA Forest Service, found that postfire plant production increased 56 percent the year a fire occurred. Where grazing occurred the second and third years after fire, the postfire pastures yielded slightly more or had similar production as unburned sites. A companion study demonstrated that plant response to fire was similar whether sites were mowed or not mowed after fire. These combined results suggest it isn’t necessary to prohibit or delay grazing in northern mixed-grass prairies after spring wildfires to maintain plant productivity and species composition. These results were similar to recent findings from the same lab indicating northern mixed prairie is resistant to grazing after summer fire.

What this means: Natural resource agencies can use these findings to support postfire grazing management decisions and reduce pasture costs for ranchers affected by wildfire.

Rangeland restoration efforts in the U.S. Intermountain Western region have historically had relatively low success rates, primarily due to the general aridity of this region and its extremely high weather variability. These dry landscapes often require multiple iterations of applied restoration practices to re-establish resilient perennial vegetation that can support wildlife communities and livestock grazing. ARS researchers and collaborators in Boise, Idaho; Burns, Oregon; Moscow, Idaho; Logan, Utah; Provo, Utah; and Woodward, Oklahoma, collaborated in developing a general strategy for adapting rangeland restoration planning and management to accommodate weather variability and help establish diverse plant communities on Great Basin rangelands that have been severely disturbed by wildfire and are dominated by introduced annual weeds. Efforts are underway to work with Federal land management agencies to implement this weather-based landscape restoration strategy via development of programmatic management plans on southern Idaho public rangelands.

What this means: Implementing these plans could improve rangeland restoration success rates on millions of acres of disturbed rangeland throughout the U.S. Intermountain Western region.

The growing demand for fish and seafood products is accelerating development of aquaculture nationally, and alternative feed ingredients that are sustainably produced and widely available are needed to meet these demands. Some alternative proteins extracted from crop plants lack essential nutrients or have anti-nutritional components. ARS scientists in St. Paul, Minnesota, and University of Minnesota collaborators tested a protein concentrate made from alfalfa foliage as a replacement for fishmeal in yellow perch diets. They found fish that consumed this concentrate had the same growth rates as fish consuming fishmeal, which indicates alfalfa protein concentrate can substitute for this feed ingredient. A simple heat treatment after juicing produced the highest yield of protein concentrate from alfalfa leaves.

What this means: Alfalfa stems, the "cake" resulting from leaf juicing, and the de-proteinized juice have potential as additional value-added products in alfalfa biorefining, while high-value alfalfa products will increase the value of crop and farm gate revenue.

Winter wheat, cereal rye, and triticale are important cool-season annual forages and cover crops throughout the Great Plains and Midwest. However, there is little information available that compares the profit from grazing these three cover crops. ARS scientists at Lincoln, Nebraska, and university colleagues compared steer performance in a 3-year grazing trial by no-till seeding the three different crops into soybean stubble in the autumn, then allowing cattle to graze on the crops in the following spring. Spring forage production was variable, but generally, cereal rye had greater growth than either triticale or winter wheat. Based on the 3-year average animal gains per acre and returns of $0.60 per pound of animal gain, triticale had a 3-year mean net return of $25.15 per acre per year, followed by winter wheat at $9.13 per acre per year, while cereal rye lost money at -$11.70 per acre per year. Since these small grain crops help protect and enhance soil resources as well as provide livestock forage, grazing cover crops could help producers recover costs and increase the cost-effectiveness of the crop-livestock system.

What this means: This research gives livestock producers information needed to select the most profitable cover crop for eastern Nebraska.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 2.5

During FY 2018, ARS will:

1. Provide improved germplasm and cultivars that can be released for pasture, harvested forages, turf, biofuels, rangeland restoration, and conservation.
2. Provide forage, pasture, and rangeland management technologies and strategies that reduce inputs while improving livestock performance and sustaining the environment.

During FY 2019, ARS will:

1. Provide improved germplasm and cultivars that can be released for pasture, harvested forages, turf, biofuels, rangeland restoration, and conservation.
2. Provide forage, pasture, and rangeland management technologies and strategies that reduce inputs while improving livestock performance and sustaining the environment.
3. Develop methods to assess soil microbial and total soil ecosystem complexity in rangelands, pasture, hay, and turf lands to understand and manage soil systems for improved production, while at the same time conserving the soils for future resource needs.

During FY 2020, ARS will:

1. Provide tools and management practices for livestock producers and rangeland managers that enhance sustainable production and increase landscape resilience.
2. Develop and provide new genomic, transcriptome, proteomic, and metabolomic tools to support cultivar development of forage grasses, turfgrasses, and legumes - and to determine implications for plant production, fitness, and forage and turf utilization under different and varying environmental conditions.
3. Develop methods to critically evaluate rangeland management and restoration practices and complimentary technologies that can be used to improve the establishment of desirable plants at sites in need of restoration.
4. Develop management practices that use forage crops to improve soil health, water quality, plant productivity and economic return.

Goal 2.6 – Develop Integrated Solutions to Solve Challenges Related to Agricultural System Productivity, Profitability, Energy Efficiency, and Natural Resource Stewardship

NATIONAL PROGRAM 216 - AGRICULTURAL COMPETITIVENESS & SUSTAINABILITY

Profitable farms are the basis of vibrant rural economies. Consumers benefit from agricultural production that provides abundant choices of products at relatively low costs. Even though commodity prices are now high, many farms still have difficulty responding to changing market conditions and the high costs of fuel and other purchased inputs. In addition, there is increasing competition from overseas markets where production costs are comparatively low. At the same time, continued advancement of conservation goals is needed to enhance the natural resource base upon which the nation not only depends for food, feed, fiber, and renewable energy, but also for supplies of fresh water, clean air, and healthy ecosystems. The challenges producers face regarding productivity, profitability, and natural resource stewardship are complex, so the solutions to these challenges will not be simple.

Producers and natural resource managers need holistic solutions to the complex problems they face. Not only do they need to decide what the best production methods, improved varieties, and advanced technologies to use, they want to know how these innovations can be best incorporated into their operations and whether their investment will increase their ability to compete in the market. Though many of the problems producers face are the same across the country, it is accepted that each region and every farm is different, so there are no "one-size-fits-all" solutions.

These challenges are not unique to the United States. The United Nations Food and Agriculture Organization (FAO) addressed similar issues in their Strategic Framework 2010-2019. Strategic Objective A—*Sustainable Intensification of Crop Production*—seeks to increase production per unit land area to meet world food needs and "requires the integration and harmonization of all appropriate crop production policies and practices aimed at increasing crop productivity in a sustainable manner, thereby meeting key millennium development goals aimed at reducing hunger and preserving the natural resources and environment for future use."

Interdisciplinary systems research provides an approach to understand how different kinds of farm enterprises function, and how changing or introducing new technology will affect their productivity, profitability, energy efficiency, and natural resource stewardship. Finding the best combinations of practices will help producers achieve their production goals, while enhancing the environmental goods and services derived from agricultural lands. Diverse and dynamic agricultural systems are needed that can adjust to changing environmental and market conditions to increase the long-term financial viability and competitiveness of farms, enhance natural resource quality, contribute to the vibrancy of rural communities, and increase the food, fiber, and energy security for the Nation and the world. This research will contribute to making sustainable intensification of agriculture a reality.

PERFORMANCE MEASURE FOR GOAL 2.6

Develop integrated solutions to solve challenges related to agricultural system productivity, profitability, energy efficiency, and natural resource stewardship.

FY 2017 PERFORMANCE REPORT FOR GOAL 2.6 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will develop integrated solutions to solve challenges related to agricultural system productivity, profitability, energy efficiency, and natural resource stewardship.

Mid-Atlantic strawberry production is limited to a short 5-week harvest. The fresh berry market would benefit by adopting repeat-fruiting cultivars, but new production systems are needed for the cultivars. ARS scientists in Beltsville, Maryland, tested and evaluated low-tunnel raised-bed production systems for repeat-fruiting cultivars. The results indicated that repeat-fruiting cultivars could be successfully grown over several months, which would lengthen the harvest season. Yields and berry quality were higher under covered beds than under non-covered beds. Warmer air, crown, and soil temperatures extended the growing season, and the light quality within the tunnels was also better for the berries. The researchers used the study data for mathematical model development to further improve the design and management of these systems.

What this means: This research gives breeders and growers an environment suitable for generating economically viable strawberry yields over an extended period for harvest.

ARS researchers at Mississippi State, Mississippi, studied how long nitrogen persists in minimal tillage systems after using subsurface banding to amend soils with broiler litter. When pelletized poultry litter (PPL) was applied in sub-surface bands for 3 years, the PPL provided at least 56 kilograms of nitrogen per hectare for each of the 2 years following 2013 PPL applications. Beneficial fertilizer effects were observed in cotton lint yield, plant leaf density, and nitrogen uptake. The residual effect of PPL containing 84 kilograms of nitrogen per hectare increased lint yield by approximately 10 percent during 2014 and 5 percent during 2015, which were higher than yields resulting from standard nitrogen fertilization rates of 140 kilograms per hectare.

What this means: This result indicates that the option for reduced fertilizer application rates exist during years following PPL application, which would reduce fertilizer application costs in minimal tillage systems and reduce probabilities for excess nitrogen loss to the environment.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 2.6

During FY 2018, ARS will:

1. Develop integrated solutions to increase agricultural system productivity, profitability and natural resource stewardship with metrics to describe the sustainability of the solutions.

During FY 2019, ARS will:

1. Develop integrated solutions to increase agricultural system productivity, profitability and natural resource stewardship with metrics to describe the sustainability of the solutions.

During FY 2020, ARS will:

1. Develop new options for alternative crops to be used in rotations with existing crops for greater production resilience, efficiency, and economic return.
2. Develop strategies to increase efficiency of water and nutrient use that enable reduced input costs and losses to the environment.
3. Develop strategies for increased resilience of production systems to extreme weather events.
4. Develop sustainability metrics appropriate for assessing trends of the long term viability of local production systems.

GOAL AREA 3: CROP PRODUCTION AND PROTECTION

Research conducted by ARS' Crop Production and Protection Program (CPP) National Programs will deliver science-based information and technologies to meet:

- Producers' needs for increased crop productivity and quality, protection from diseases and pests, and economically and environmentally sustainable methods of crop production;
- Consumers' demands for a ready supply of high quality, safe, affordable, and nutritious food;
- Workers' needs for a safe working environment;
- The public's desire to protect the environment; and
- The global community's needs for food security.

To meet these needs, ARS will conduct research that addresses the national priorities of genetic resource conservation, genomics, and genetic improvement; prevention and treatment of plant diseases; identification and management of arthropod and weed pests, including quarantine pests; improved crop management strategies; and the development of methyl bromide alternatives. The research of the Crop Production and Protection National Programs is well integrated with other ARS research in Animal Protection and Production; Natural Resources and Sustainable Agricultural Systems; and Nutrition, Food Safety and Quality. Through the National Invasive Species Information Center and Alternative Farming Systems Center of the National Agricultural Library, key information will be disseminated to agricultural producers, the research and education community, and the general public.

Goal 3.1 – Protect, Expand, And Enhance the United States' Crop Genetic Resource Base, Increase Scientific Knowledge of Crop Genes, Genomes, Biological Processes and Systems, and Deliver Economically and Environmentally Sound Technologies that Improve the Production Efficiency, Quality, Health and Value of the Nation's Crops

NATIONAL PROGRAM 301 - PLANT GENETIC RESOURCES, GENOMICS, AND GENETIC IMPROVEMENT

NATIONAL PROGRAM 305 - CROP PRODUCTION

U.S. crop production depends on new and improved varieties of crops—developed faster and for less cost—that are competitive in the market increasingly tailored to meet the complex demands for food, feed, fiber, ornamentals, and energy; and adapted to an increasingly challenging global climate. To do so, ARS research will harness the inherent genetic potential of plants. This research will develop, and effectively apply, new knowledge of crop genes, genomes, and the control and expression of genes to accelerate productivity and improve the quality of crops; realized via traditional and novel plant breeding methods.

Genetic resources are the foundation of our agricultural future. ARS crop gene banks contain the sources of resistance to biotic and abiotic stresses and new genes to improve the quantity and quality of food, feed, energy, fiber, and ornamental crops. To ensure that these genes are available for research and breeding, ARS will continue to acquire and conserve crop genetic resources, develop more effective screening methods for identifying superior traits, characterize the genetic profiles of gene bank holdings, ensure that genetic resources are distributed where and when they are needed, and safeguard these collections and their associated information for future generations.

New ARS genetic technologies will address the specific needs for higher crop yields; more durable and effective tolerance to abiotic stresses including drought, heat, cold, freezing, and flooding; more efficient crop use of key inputs such as water and nutrients; more durable and effective pest and disease resistance; control of flowering time; enhanced product composition and nutritional quality; value-added traits; and conversion efficiency to biofuels. ARS research will elucidate how crop traits are controlled by underlying genetic systems, how these traits are affected by environmental factors during crop production, and how to enhance traits by incorporating novel sources of genetic variation from underexploited genetic resources or by genetically engineering such traits. ARS will devise new crop genetic improvement methods that incorporate advances in genome sequencing and analysis, molecular genetics, computational biology, and metabolic engineering. New crop breeding theories and strategies will be developed to more effectively capture the intrinsic genetic potential of germplasm—especially to improve key agronomic and horticultural traits—resulting in crops tailored for consumer and producer needs.

ARS will continue to lead the development of crop genetic and genomic information management and database systems that broadly support and enhance crop research, from germplasm improvement and breeding to genetic and genomic analyses. New tools will be generated to efficiently incorporate valuable new data into databases, extract key information from the massive quantity of data safeguarded in those databases, identify the important properties of genes, apply that knowledge to crop improvement, and build on genetic advances in one crop so as to accelerate genetic gains in others.

The Nation's economic vitality depends on the ability of U.S. crop producers to grow and market food, fiber, ornamentals, industrial products, feed, and fuels profitably; while enhancing the natural resource base on which crop production depends. Future economic success for U.S. producers depends on increased productivity, access to new markets for specialized products, new technologies that generate new opportunities for U.S. farmers, and new tools and information to mitigate risks and enable rapid adjustments to changing market conditions. The agricultural sector is challenged by a wide variety of resource, climatic, economic, and social factors that require an equally diverse array of strategies and solutions for successfully meeting those challenges.

Contemporary U.S. crop enterprises for annual, perennial, and greenhouse crop production are complex and depend on access to and successful integration of highly diverse components, such as a steady stream of superior crop varieties, new strategies for mitigation of crop losses from biotic and abiotic stresses, and mechanization and automation of undesirable or labor intensive activities. The development of successful new production systems to sustain or increase crop yield and quality requires focusing on 1) productive and profitable crop management strategies for new and traditional crops that conserve natural resources; 2) efficient and effective integrated management strategies for multiple pests; 3) mechanization of management activities to address labor constraints; and 4) improved crop management models and decision aids.

Pollination is a critical element in agriculture as well, because honey bees pollinate more than 130 crops in the United States and add $15 billion in crop value annually. Declining honeybee populations and honey production due to Colony Collapse Disorder (CCD) require special attention. CCD has now increased honey bee mortality to more than 30 percent. Also, as new crops are introduced and stresses on honeybees increase, pollinators will be continuously required for specific crops or protected environments.

Improved production systems must address the needs of small, intermediate, and large field-, greenhouse-, orchard-, and vineyard-based farming enterprises for more efficient conventional, organic, and controlled-environment production methods and strategies. New crop production technologies must increase production efficiency, conserve energy and natural resources, and provide resilience in the face of abiotic and biotic stresses; while maintaining or enhancing productivity and product quality.

Key outcomes of this research will be new technologies (such as superior crop varieties; enhanced breeding stock; more effective crop and pest management strategies; improved sensors, robotics, and spray application equipment; improved decision support systems; more efficient production systems) and information that sustain U. S. crop production and enable producers to compete more effectively in the global market place. The U. S. national capacity to exploit the genetic potential of crops efficiently and effectively is maintained, and U.S. crop productivity and efficiency are enhanced.

PERFORMANCE MEASURE FOR GOAL 3.1

Develop knowledge, strategies, systems, and technologies that maximize the production efficiency of our annual, perennial, greenhouse, and nursery cropping systems. Develop new technologies and tools contributing to improving these systems to meet current and future food crop production needs of diversified consumers, while ensuring economic and environmental sustainability and production efficiency, health, and value of our nation's crops.

FY 2017 PERFORMANCE REPORT FOR GOAL 3.1 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will breed superior new crops, varieties, and enhanced germplasm.

Downy mildew and rust are plant diseases that can seriously reduce sunflower yields. Commercial confection (i.e., edible) sunflower breeders rely on ARS to provide inbred strains of sunflower with disease resistance, but very few suitable confection sunflower inbred lines are available with resistance to both downy mildew and rust. ARS scientists in Fargo, North Dakota, have developed and released three germplasm lines of sunflower that are resistant to both diseases. Each germplasm carry a gene for downy mildew resistance combined with one for rust resistance, thus providing resistance to all known races of North American rust and downy mildew.

What this means: This represents the first confection germplasm that exhibits combined resistance to both downy mildew and rust. Molecular markers linked to both disease-resistance genes were developed and released to the sunflower industry, enabling breeders to develop additional hybrids with resistance to multiple pathogens, and thus assuring sustainable sunflower production in the presence of these two devastating diseases.

High temperatures (>90°F) damage soybean seed by reducing seed germination and seedling vigor. They also cause seed coat impermeability and green seed discoloration. Unacceptable seed quality and economic loss are major challenges for soybean producers where temperatures are consistently high, such as the Mississippi Delta region. There has been little attention in commercial breeding programs to address the issue, but ARS researchers in Stoneville, Mississippi; Columbia, Missouri; Jackson, Tennessee; and Raleigh, North Carolina, discovered a heat tolerance gene, and developed and released a maturity group IV soybean germplasm line to seed companies and public breeders. This germplasm line maintains excellent seed germination and high seed quality under elevated temperatures.

What this means: 'DS25-1' is the first U.S. soybean germplasm release to address heat tolerance in soybean, and it will enable breeding to develop better seed quality in high-temperature stress environments. Commercial and public soybean breeders are now using DS25-1 in their breeding programs to develop heat-tolerant soybean cultivars for producers.

Late season rains can delay pinto bean harvests and cause the beans to darken prematurely, which reduces their market value and costs U.S. growers more than $30 million every year. Current varieties lack the genetic potential to restrict darkening. ARS researchers at Prosser, Washington, worked with scientists at North Dakota State University to develop and release the new pinto bean cultivar 'Scout.' Scout has a slow darkening seed trait that protects pinto beans from premature darkening, and also has better canning quality than the industry pinto bean standard 'Othello.'

What this means: Scout provides growers in the western United States and intermountain plains with a new bean cultivar that has excellent value and market quality, and will help reduce grower losses associated with delayed harvests and reduced bean marketability.

Indicator 2: During 2017, ARS will devise innovative approaches to crop genetic improvement and trait analysis.

Wheat, a staple of life for billions of people, had a farm gate value of about $10 billion in the United States in 2015. For centuries, wheat production has been threatened by a highly virulent microbe called wheat stem rust, which is able to rapidly change into new dangerous types. New and highly virulent races of the wheat stem rust pathogen known as Ug99 have arisen in Africa and are a severe threat to U.S. and world wheat production. To protect the U.S. wheat crop from Ug99, new research tools are needed to help wheat breeders identify new sources of genetic protection. ARS researchers in Aberdeen, Idaho, and St. Paul, Minnesota, discovered genetic markers that speed the selection for the resistance gene Sr28, which is effective against Ug99, from wheat breeding stocks. In addition, a potentially new type of genetic resistance that acts at the adult wheat plant stage was identified and its location has been mapped on the wheat genome.

What this means: These advancements are substantially aiding U.S. wheat breeders by providing them with new wheat varieties that are resistant to stem rusts.

Blueberry plants infected with blueberry fruit drop disease lose all of their unripe fruit before harvest. The disease was first detected in the Pacific Northwest more than a decade ago, but the cause was unknown, making eradication difficult. ARS researchers in Corvallis, Oregon, identified a new virus, Blueberry fruit drop-associated virus (BFDaV), on infected plants and found that 35 plants showing disease symptoms were infected with the virus, while 31 plants free of disease symptoms were not infected. These results indicated a strong correlation between the virus and the disease. In 2015 and 2016, researchers conducted a blueberry virus survey in the major North America blueberry producing regions and sampled around 4,200 plants. The virus was only found in plants from northwest Washington and British Columbia, as well as in one 'Aron' blueberry plant from Finland housed at an ARS unit in Corvallis, Oregon. Despite its very limited distribution and slow rate of spread in the field, efforts are now underway to eradicate this virus from blueberry fields in North America.

What this means: This research support eradication efforts which will help protect blueberry producers from crop losses.

Indicator 3: During 2017, ARS will expand crop genomic information resources and advanced bioinformatic capabilities.

Bradyrhizobium bacteria has the ability to form nodules on the roots of legume plants where nitrogen fixation can occur. Soybean, the second largest field crop in the United States, can produce its own nitrogen through its association with the bacteria. But very little is known about the genetics of the rhizobium organism, so research has been restricted to identifying the genes responsible in soybean-bacterium interactions. ARS scientists in Beltsville, Maryland, were part of an international scientific team that sequenced the genome of a specific species of rhizobium, *Bradyrhizobium elkanii*.

What this means: Having the complete genome sequence will help scientists identify all the genes and gene activity responsible for soybean-rhizobium interactions and nitrogen fixation. The sequence will be useful to companies, universities, and government laboratories conducting research on soybean association with these specific bacteria, and improve soybean production by increasing nitrogen fixation.

A complete draft genome that covers all chromosomal regions greatly helps plant breeders identify and select molecular markers to be used in the development of new germplasm with desirable traits. Previous studies identifying molecular markers in hop used a draft assembly that covered only 63 percent of the genome, which meant molecular markers for important genetic traits might still be overlooked. ARS scientists in Corvallis, Oregon, worked with collaborators at Oregon State University and Pacific Biosciences to sequence and assemble a new draft hop genome that covers approximately 98 percent of the genome. Previous draft genomes were made up of relatively short stretches of DNA sequence data with average assembled size of such sequences being 40,000 base pairs while the new draft genome has an average size of assembled sequences equaling 750,000 base pairs.

What this means: This new draft genome will enable the precise identification of molecular markers and genes linked to traits of economic importance in hop and support the development and use of molecular tools for other uses, such as identifying unknown hop varieties.

Indicator 4: During 2017, ARS will conserve and encourage the use of plant and microbial genetic resources and associated information.

The ARS National Plant Germplasm System (NPGS) conserves more than 500,000 individual germplasm samples in the form of seeds. Monitoring the viability of all of those seed samples during storage is an essential NPGS operation, but it is labor-intensive, consumes valuable germplasm, and does not predict when seeds would begin to die. ARS scientists in Fort Collins, Colorado, have introduced a new method to detect "seed aging" that measures the integrity of a key genetic molecule within seed cells. This new assay has the potential for automation, generates highly quantitative data about seed aging, closely corresponds to germination potential of seeds, and consumes about one-tenth the number of the valuable seeds required for germination tests.

What this means: Implementing this technology will ensure that scientists will be able to detect signs of seed deterioration in NPGS seed collections much earlier and respond accordingly. This will help reduce labor costs and the number of seeds required for these tests, and enhance the effectiveness of NPGS activities that conserve valuable plant genetic materials.

Mango ranks as the fifth most-consumed fruit in the world, and millions of acres internationally are used for mango production. Current U.S. mango production takes place on around 2,300 acres, but production is increasing and U.S. producers have had a substantial influence on the supply of new cultivars for international trade. Traditional mango breeding efforts require 15 years or more to produce new tree cultivars. ARS researchers in Miami, Florida, and cooperators in Australia, Brazil, Indonesia, Senegal, and Thailand created the first genetic map for mango. By knowing where desirable genes are located on the genetic map, mango breeders can apply genetic markers to select trees with desirable traits, such as fruit color, shelf life, and disease resistance, quickly and early in the seedling stage.

What this means: Since most traditional mango breeding costs involve maintaining and evaluating trees for years, a genetic map gives U.S. and international breeders a powerful tool to reduce costs and streamline mango cultivar breeding programs.

Indicator 5: During 2017, ARS will expand fundamental knowledge of plant biological and molecular processes.

Variations in atmospheric conditions will likely affect U.S. agriculture and could threaten future food production and food safety. Sweet corn typically emits chemical signals in the form of odors which attract parasitic wasps that lay eggs in the caterpillar pests and kill them. ARS researchers in Gainesville, Florida, conducted a study to determine if high atmospheric carbon dioxide levels affect how sweet corn defends itself against insect pests. The scientists found that odor levels emitted by sweet corn diminished when the corn was grown under high conditions of carbon dioxide.

What this means: These findings suggest that growers, particularly organic growers who use such wasps as a form of biocontrol, may need to modify their pest management strategies if atmospheric carbon dioxide levels rise.

Sorghum biomass from stalks and leaves is an important forage crop for livestock, and sorghum is also being developed as a bioenergy crop for advanced or second generation biofuels production. Advanced biofuels are derived from the breakdown of the cellulose and hemicellulose components of biomass into sugars and their subsequent conversion into biofuel molecules. A third biomass component, lignin, impedes breakdown of biomass in either livestock digestive systems or bioenergy conversion processes. ARS scientists in Lincoln, Nebraska, and Washington State University scientists identified and examined two types of enzymes involved with lignin synthesis and found one of these enzymes is also involved in making a specific type of lignin associated with plant defenses against pathogens.

What this means: This research highlights the dual functions of this enzyme in lignin synthesis, and may lead to ways to protect plants from pathogens or insects. It will also help researchers develop new ways to alter the biomass composition of sorghum and other grasses for improved bioenergy conversion.

Indicator 6: During 2017, ARS will develop more effective methods to enhance biotechnology for crop improvement.

Sharka is a devastating disease of stone fruit caused by plum pox virus (PPV). It almost completely ruined the plum industry in Eastern Europe and caused significant losses in most plum producing regions arounds the world. ARS scientists in Kearneysville, West Virginia, and international partners conducted field trials of 'Honeysweet' plum trees planted in PPV stricken regions and found the trees remained largely free of virus and symptom for over 2 decades.

What this means: 'Honeysweet' was officially released as a publicly available cultivar in the United States and the first trees are now available for purchase from U.S. nurseries. ARS is currently working with international partners to make 'Honeysweet' available in the European Union.

Studies of gene flow between crops and their wild relatives support farming, breeding management practices, and help identify potential risks associated with transgene escape. Wild carrot occurs widely across the United States, but gene flow between wild and cultivated carrots has not been studied. ARS scientists in Madison, Wisconsin, and collaborators in Tennessee used genetic markers to evaluate carrot gene flow in two U.S. regions. They found evidence of substantial gene flow, which indicated wild and cultivated populations growing near each other are able to exchange pollen and transfer genetic information.

What this means: This research provides seed companies with information they can use to reduce risks wild carrots might pose to their cultivated carrot relatives, and help explain carrot pollination biology.

Indicator 7: During 2017, ARS will develop crop production strategies to optimize crop genetic potential, mitigate losses due to biotic and abiotic stresses, and increase production efficiency.

ARS research was critical in the domestication and establishment of *Camelina* and pennycress (*Thalaspi* spp.) as new oilseed crops. Both crops require sound agricultural management practices for their successful production. Although ARS has published information on effective crop production systems that include these crops, optimum seeding methods for best stand establishments have not been determined. ARS researchers in Morris, Minnesota, developed better methods for timing and planting both crops that can improve plant establishment and potentially increase seed and oil yields. Much of the research information developed on *Camelina*, including the use of winter varieties in dual cropping systems, was summarized in an ARS-produced growers guide, and published in two different review articles in collaboration with universities.

What this means: In addition to providing new alternative crops for growers, this work offers producers a way to teach themselves how to grow *Camelina* and pennycress for maximum economic benefit.

Conducting on-farm evaluations of pest control and determining its economic feasibility is a necessary procedure to assure successful adoption of new spray technologies by commercial horticulture enterprises. ARS researchers in Wooster, Ohio, developed a new intelligent sprayer that targets insect pests and tested it in three commercial nurseries in Ohio and Oregon. The efficacy of the sprayer for pest control treatments was compared with two types of conventional air-assisted sprayers. Variable rates from the intelligent sprayer were achieved automatically based on plant presence, canopy structure, and foliage density. Compared with conventional sprayers with comparable and effective insect control, the intelligent sprayer used 30 to 78 percent less spray volume (and thus fewer chemicals) to control pest insects.

What this means: This intelligent sprayer offers an economically and environmentally responsible spray system to controlling pests.

Using cover crops in vineyards helps prevent soil erosion and increases soil structure, which benefits grape vines. However, the long term impact of no till management strategies is hard to predict without long term studies. ARS researchers in Davis, California, compared two treatments over 20 years that measured soil health in the vineyard floor. In one treatment the cover crop was tilled once annually and in the other treatment the permanent cover crop was maintained without tillage. No tillage treatment resulted in greater increases in microbial biomass, biological activity, total soil carbon content, and specific pools representing stable organic carbon contributing to soil carbon storage that mitigates greenhouse gas emissions. Soil aggregate stability was greater in the no-till, permanent cover crop treatment, indicating these soils possess greater resistance to degradation from erosion caused by runoff and precipitation.

What this means: These findings show that even a single tillage pass per year can diminish soil structure and organic matter. Adopting no-till practices in California vineyards will preserve soil health, improve soil nutrient availability, and reduce fossil fuel use incurred due to use of tractors for tillage.

Indicator 8: During 2017, ARS will improve pollinator health, bee systematics and germplasm lines, and pollination.

The lack of reliable sperm cryopreservation is a key roadblock to the development of a comprehensive and integrated honey bee breeding program. To address this problem, ARS researchers in Fargo, North Dakota, in collaboration with ARS scientists in Baton Rouge, Louisiana, and the ARS National Bee Gene Bank

Program in Fort Collins, Colorado, developed a better method to cryopreserve honey bee spermatozoa, including development of the Fargo Honey Bee Extender Medium.

What this means: This medium not only improves sperm quality after cryopreservation, but allows for semen shipment at room temperature before and after storage, potentially improving the accessibility of cryopreserved samples for bee breeding programs worldwide.

Increased attention on how agricultural insecticides may harm honey bees has increased scrutiny on how insecticides are tested. ARS researchers in Baton Rouge, Louisiana, tested the effect of insecticides on some commercial honey bee stocks and found that bee age and genetics affected the bees' response to the insecticides.

What this means: The results can be used to help in risk assessments of different genetic types of bees. The researchers established baseline information for future assessments and suggest that standardizing testing protocols would be beneficial.

ARS scientists in Tucson, Arizona, studied the effect of fresh and aged nutrient sources on honey bee health. Bees fed aged nutrition exhibited impaired development and increased mortality and developed a significantly different microbiome (mix of microbes), differences that extended throughout the entire alimentary tract. The scientists determined that consuming an aged nutrient source resulted in a significant reduction of the core ileum bacterium *Snodgrassella alvi* and a corresponding increase in the abundance and diversity of opportunistic gut pathogens. The researchers found that the abundance of *S. alvi* in the ileum correlated with host survival and development. The inverse was true for three different bacterial species, reinforcing their role as opportunistic pathogens or disease markers. Collectively, findings suggest that the early establishment of *S. alvi* is associated with healthy nurse bee development, suppressing opportunistic bacteria in the ileum.

What this means: This knowledge is used by customers and stakeholders in decisions about which supplemental diet to provide to bees.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 3.1

During FY 2018, ARS will:

1. Breed superior new crops, varieties, and enhanced germplasm.
2. Devise innovative approaches to crop genetic improvement and trait analysis.
3. Expand crop genomic information resources and advanced bioinformatic capabilities.
4. Conserve and encourage the use of plant and microbial genetic resources and associated information.
5. Expand fundamental knowledge of plant biological and molecular processes.
6. Develop more effective methods to enhance biotechnology for crop improvement.
7. Develop crop production strategies to optimize crop genetic potential, mitigate losses due to biotic and abiotic stresses, and increase production efficiency.
8. Improve pollinator health, bee systematics and germplasm lines, and pollination.

During FY 2019, ARS will:

1. Breed superior new crops, varieties, and enhanced germplasm.
2. Devise innovative approaches to crop genetic improvement and trait analysis.
3. Expand crop genomic information resources and advanced bioinformatic capabilities.
4. Conserve and encourage the use of plant and microbial genetic resources and associated information.
5. Expand fundamental knowledge of plant biological and molecular processes.
6. Develop more effective methods to enhance biotechnology for crop improvement.
7. Develop crop production strategies to optimize crop genetic potential, mitigate losses due to biotic and abiotic stresses, and increase production efficiency.
8. Improve pollinator health, bee systematics and germplasm lines, and pollination.

During FY 2020, ARS will:

1. Breed superior new crops, varieties, and enhanced germplasm.
2. Devise innovative approaches to crop genetic improvement and trait analysis.
3. Expand crop genomic information resources and advanced bioinformatic capabilities.
4. Conserve and encourage the use of plant and microbial genetic resources and associated information.
5. Expand fundamental knowledge of plant biological and molecular processes.
6. Develop more effective methods to enhance biotechnology for crop improvement.
7. Develop crop production strategies to optimize crop genetic potential, mitigate losses due to biotic and abiotic stresses, and increase production efficiency.
8. Improve pollinator health, bee systematics and germplasm lines, and pollination.

Goal 3.2 – Protect Our Nation's Crops

NATIONAL PROGRAM 303 - PLANT DISEASES

NATIONAL PROGRAM 304 - CROP PROTECTION AND QUARANTINE

Economic losses of agricultural crops and natural ecosystems due to arthropods, plant pathogens, nematodes, and weeds are considerable, with estimates in the tens of billions of dollars each year to agriculture, landscapes, and forests in the United States. Losses are due to reduced yields, lower product quality or shelf-life, decreased aesthetic or nutritional value, and food and feed contaminated with toxic compounds. Pest management strategies include cultural, biological, physical, and chemical methods. Non-chemical methods based on biological knowledge continue to expand, but the United States continues to depend heavily on chemical control to produce agricultural commodities. For instance, in 2007 more than 850 million pounds of pesticides (including herbicides, insecticides, fungicides, and nematicides) were applied to agricultural crops in the United States to protect these commodities from pests and pathogens (Pesticides and Industry Sales and Usage; 2007 and 2007 Market Estimates, EPA).

Maintenance of our arsenal of valuable management strategies is a constant challenge, as inherent disease and pest resistance in crops declines while pests become resistant to chemical controls, new pest problems emerge, new regulatory requirements are enacted, and production costs increase with rising energy costs. Further, the problem of losses due to pests and plant diseases does not end in the field or with the harvest. Insects and diseases reduce the quality of stored grain and other stored products, and it is estimated that post-harvest losses to corn and wheat alone amount to as much as $2.5 billion annually. Pests and diseases can also impede foreign trade. Imported commodities as well as those destined for export must be protected from endemic and exotic pests. Exotic insect, disease, and weed pests that threaten our food, fiber, and natural ecosystems are another mounting concern, as world trade and travel continues to expand. Invasive species such as the brown marmorated stinkbug and the Asian soybean rust directly threaten U.S. agricultural crops, while other invasive insects transmit devastating viral and bacterial diseases, such as citrus greening, that threaten entire agricultural industries. Still other invasive insects, such as the Asian longhorned beetle and the sudden oak death pathogen, decimate our forests and urban landscapes, while invasive weeds reduce biodiversity, displace native species, and cost billions of dollars annually to control. Management of arthropod pests, plant diseases, and weeds is essential for providing an adequate supply of food, feed, fiber, and ornamental crops, but effective control depends on understanding the biology and ecology of these deleterious organisms as well as beneficial ones.

Numerous diverse approaches are needed to protect U.S. crops from arthropods, plant pathogens, nematodes, and weeds. To manage plant pathogens and nematodes, ARS will: 1) develop and improve rapid and reliable methods for detection and identification of plant pathogens and nematodes; 2) enhance knowledge of the etiology of plant diseases and systematics of their pathogens; 3) provide in-depth knowledge of the biology, ecology, and epidemiology of plant pathogens and their interactions with hosts and vectors to identify targets for new disease management strategies; 4) develop and deploy host resistance against plant diseases and nematodes, and 5) develop biologically based and integrated disease management strategies.

To reduce the impact of weeds on the nation's agricultural and natural systems, ARS will 1) develop novel weed management solutions to control the reproduction and spread of invasive and weedy plants based on new knowledge derived from plant genomics, biochemistry, and physiology; 2) expand integrated weed management programs by incorporating newly identified natural products or natural enemies, such as fungi, bacteria, viruses, nematodes, and insects; 3) determine the mechanisms of herbicide resistance in weeds and enhance knowledge of the biology, physiology, and ecology of weeds, so as to develop cropping system methods that mitigate herbicide resistance development and spread; 4) develop spatial models to monitor and control invasive plants in complex landscapes; 5) develop recommendations for restoring natural systems in ways that prevent weed invasions following effective biological control; and 6) identify effective weed management solutions for reduced tillage, low herbicide input, and organic production systems.

To ensure the cost effective management and control of native and invasive arthropod plant pests, ARS will 1) develop new bioinformatic tools that enhance insect species identification; 2) identify genetic, biological, and ecological determinants of plant insect pests that can be manipulated to improve their control; 3) determine critical factors involved in disease transmission by insects; 4) improve insect monitoring and capturing methodologies by identifying, synthesizing, and field-testing semiochemicals; 5) develop new biological, chemical, and cultural methodologies to control plant insect pests; 6) improve or develop sterile insect technique technologies to eradicate insect pests; and 7) develop systems for rearing natural enemies that have been demonstrated to be effective and safe biological control agents.

The key outcomes of this research will be the knowledge and improved capacity needed to protect plants in agricultural and natural systems, including the safe production and trade of food, feed, fiber, ornamentals, industrial products, and biofuels. This research and the transfer of resulting technologies will provide globally competitive and sustainable agricultural systems, safe and nutritious food, and healthy landscapes.

PERFORMANCE MEASURE FOR GOAL 3.2

Provide scientific information to increase our knowledge of plant genes, genomes, and biological and molecular processes to protect crops and cropping systems from the negative effects of pests and infectious diseases. Develop sustainable control strategies for crop pests and pathogens based on fundamental and applied research that are effective and affordable, while maintaining food safety and environmental quality.

FY 2017 PERFORMANCE REPORT FOR GOAL 3.2 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will continue to identify and characterize resistance genes in crop plants for insect, nematode, and plant pathogens, to enhance opportunities for developing host plant resistance, and to incorporate such genes into commercially acceptable varieties.

The root-knot nematode is found throughout the Cotton Belt, and crop rotation with non-host crops can provide short-term nematode suppression. But growers prefer to raise plants that have nematode resistance rather than rotate their crops, which is usually a challenge to implement. Chromosome 14 holds one of the two known genetic locations that imparts resistance to root knot nematode in cotton. But this genetic location has been only sparsely mapped, and genetic markers were not linked closely enough to the gene location to effectively select them. ARS researchers in Tifton, Georgia, collaborated with University of Georgia scientists to create new molecular markers that are more closely linked to the gene location, and demonstrated that the resistance gene(s) are confined to a much smaller segment of DNA than had been previously identified. Additionally, the researchers used the cotton genome of *Gossypium raimondii*, a precursor of modern cotton, to identify 20 genes in the newly delineated region that could be involved in nematode resistance.

What this means: The improved markers allow better pinpointing of their precise location, and breeding programs are now developing resistant germplasm with the markers. Identification of these potential resistance genes advances researchers closer to the goal of identifying specific resistance genes and their function.

Growing resistant varieties is the most effective, economical, easy-to-use, and environmentally friendly approach to control stripe rust in wheat. Germplasm with well-characterized and effective resistance genes is essential and increases the efficiency of developing new resistant varieties. ARS scientists in Pullman, Washington, recently released twenty-nine new wheat germplasm lines. Fifteen lines (PI 679598 – PI 679626) have a single different resistance gene and fourteen lines each have a combination of two linked resistance genes. These lines also have improved agronomic traits.

What this means: Use of these new germplasm lines will diversify stripe rust resistance genes used in the breeding programs. This is particularly true for lines with two linked genes, which should increase the possibility of combining two different genes on the same chromosome into new wheat varieties with high-level, durable, or long-lasting resistance.

Indicator 2: During 2017, ARS will continue to develop fundamental knowledge about biology and ecology that provides the foundation for strategies to exclude, accurately detect and identify, and mitigate arthropod and nematode pests, weeds, and plant pathogens.

Methyl bromide is no longer available as a crop fumigant and there is increasing regulatory pressure against the use of chemical fumigants, so producers need new, inexpensive, and reliable chemical-independent soil fumigation methods. Anaerobic soil disinfestation (ASD), or the elimination of plant pathogens from soil by anaerobic soil microbes and their toxic byproducts, shows great promise for use as a potential fumigant. A key determinant for ASD success, however, is the carbon source used in the ASD process, which should be easily applied by growers, readily available, inexpensive, and able to suppress a broad range of pathogens and pests. ARS researchers in Davis, California, evaluated 18 different carbon sources derived from agricultural waste and identified the five most effective sources for controlling the bacterial pathogen that causes crown gall disease and other target pathogens.

What this means: ASD using agricultural waste is proving to be a reliable and cost-effective alternative to conventional soil fumigation.

Citrus greening is currently the greatest threat to the citrus industry worldwide. It is present in all 32 citrus-producing counties in Florida and is responsible for a decline in Florida citrus production from 270 million crates in 2005 to 70 million in 2015. The Asian citrus psyllid is an insect that transmits the bacterium responsible for citrus greening from infected trees to healthy trees. ARS researchers in Fort Pierce, Florida, identified a peptide that kills the bacterium associated with the disease. They also identified a set of three different peptides that reduce the bacterium's ability to successfully move from the gut of the insect into its salivary glands, a process necessary for the transmission of the disease from infected trees into uninfected trees. The peptides also killed psyllids, causing an average of 90 percent mortality. In addition, none of the surviving insects had detectable levels of citrus greening bacteria in their salivary glands.

What this means: This peptide combination provides a new strategy to fight the psyllid and the bacterium responsible for citrus greening.

Indicator 3: During 2017, ARS will perform applied research and development to provide new, useful and safe methods and products to accurately detect, identify, and diagnose arthropod and nematode pests, weeds, and plant pathogens.

Ralstonia solanacearum (Rs) is a bacterium that causes millions of dollars of crop losses in a wide range of plant species worldwide. One strain in particular, the r3b2 subgroup, is such a threat to U.S. agriculture that is has been designated a select agent, and regulations require that all strains of Rs be designated as select agents until proven to be non-r3b2. ARS and APHIS scientists in Beltsville, Maryland, collaborated with scientists at Rutgers University to develop two portable platforms for Rs r3b2 detection - the POCKIT™ and the BLItz® - that significantly increase the sensitivity, speed, specificity, accuracy, and portability of diagnostic assays for Rs. These assays can be used to prevent the Rs r3b2 strain from entering the United States and to ensure that non-r3b2 Rs strains are not unnecessarily excluded. The palm-sized POCKIT™ can be used with previously published primers to detect as few as 10 bacteria in 32 minutes, including heat-inactivated samples and in plant tissue. The BLItz® instrument has comparable speed and sensitivity to the commercial ImmunoStrip®, with the added advantage of higher r3b2 specificity.

What this means: These two portable systems can facilitate *R. solanacearum* r3b2 detection at the ports of entry and in field settings.

Throughout the western United States, rangelands are being invaded by annual grasses such as cheatgrass and medusahead, which provide fuel for wildfires and destroy the health and usefulness of these ecosystems. The only effective way to manage invaded and degraded rangeland is to reseed the ground with desired perennial vegetation, but most reseeding attempts have failed. ARS scientists in Burns, Oregon, determined the best season to reseed, seeding rate, and weather conditions for reseeding rangeland invaded by these undesirable annual grasses. They compared the effects of spring versus autumn seeding of desired perennial grasses and various seeding rates, and determined effects on perennial and annual grass establishment under conditions typical of Western rangelands. They found that perennial grass establishment was unacceptably low when the number of annual grass seeds in the soil exceeded 150 per square yard, regardless of weather conditions. They also recommend that before reseeding with beneficial perennial grasses, land managers should sample the field to determine the number of annual grass seeds in the soil and decide if annual grasses must be controlled before proceeding.

What this means: Land managers now have solid guidelines they can use when considering rangeland re-seeding projects. Professionals who make recommendations for rangeland management can use this information to develop guidelines for stand establishment under various conditions.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 3.2

During FY 2018, ARS will:

1. Continue to identify and characterize resistance genes in crop plants for insect, nematode, and plant pathogens, to enhance opportunities for developing host plant resistance, and to incorporate such genes into commercially acceptable varieties.
2. Continue to develop fundamental knowledge about biology and ecology that provides the foundation for strategies to exclude, accurately detect and identify, and mitigate arthropod and nematode pests, weeds, and plant pathogens.
3. Perform applied research and development to provide new, useful and safe methods and products to accurately detect, identify and diagnose, arthropod and nematode pests, weeds, and plant pathogens.

During FY 2019, ARS will:

1. Continue to identify and characterize resistance genes in crop plants for insect, nematode, and plant pathogens, to enhance opportunities for developing host plant resistance, and to incorporate such genes into commercially acceptable varieties.
2. Continue to develop fundamental knowledge about biology and ecology that provides the foundation for strategies to exclude, accurately detect and identify, and mitigate arthropod and nematode pests, weeds, and plant pathogens.
3. Perform applied research and development to provide new, useful and safe methods and products to accurately detect, identify and diagnose, arthropod and nematode pests, weeds, and plant pathogens.

During FY 2020, ARS will:

1. Continue to identify and characterize resistance genes in crop plants for insect, nematode, and plant pathogens, to enhance opportunities for developing host plant resistance, and to incorporate such genes into commercially acceptable varieties.
2. Continue to develop fundamental knowledge about biology and ecology that provides the foundation for strategies to exclude, accurately detect and identify, and mitigate arthropod and nematode pests, weeds, and plant pathogens.
3. Perform applied research and development to provide new, useful and safe methods and products to accurately detect, identify and diagnose, arthropod and nematode pests, weeds, and plant pathogens.

GOAL AREA 4: ANIMAL PRODUCTION AND PROTECTION

The ARS Animal Production and Protection (APP) national programs provide the scientific information and tools to help support the U.S. food animal industries to continue to compete successfully in worldwide trade, provide the supply of nutritional animal products required by the Nation, and contribute toward global food security. APP will accomplish this mission by maximizing production efficiency and animal health through scientific innovation and the discovery and development of new technologies focused on national priorities. Strategic public-private partnerships will be established to achieve our mission, including support of government action and regulatory agencies responsible for trade, biodefense, and global food security. Emphasis will be given to genetic improvements of traits related to production and production efficiencies and germplasm conservation; understanding the mechanisms of disease resistance and the development of tools to prevent, control, or eradicate diseases that threaten the U.S. food supply and public health; and identifying and developing sustainable systems for production of high quality meat, fish, milk, and eggs that also ensure animal health and well-being. The portion of the program that produces new solutions to the many veterinary problems created by arthropod pests and vectors will be leveraged to solve related problems affecting human health and the well-being of American citizens.

Goal 4.1 – Provide Scientific Information and Biotechnologies to Enhance Management Practices that will Ensure an Abundant Supply of Competitively Priced Animal and Aquaculture Products.

NATIONAL PROGRAM 101 - ANIMAL PRODUCTION

NATIONAL PROGRAM 106 – AQUACULTURE

U.S. production systems for food animals and aquaculture face formidable challenges. One of the most exacting challenges is successful adaptation to the accelerating demands of society that impact animal productivity and product quality, including increased production, improved production efficiencies, economic and environmental sustainability, ensuring animal well-being, and improved product quality and healthfulness for consumers.

The demands placed on the national system of food animal production by a rapidly changing world can only be met by technologies that optimally harness the inherent genetic potential of animal germplasm in concert with industry stakeholders. Production systems that successfully harness that genetic potential will maximize profits, secure supply, increase market competitiveness, sustain small and mid-sized producers, maintain genetic diversity, and increase consumer confidence. These optimized production systems will also ensure the economic and environmental sustainability of animal agriculture while enabling production of animal products adequate to meet the dramatically increased demand for animal products worldwide.

Consequently, the overall mission of ARS animal production and aquaculture systems is to 1) safeguard and utilize animal and microbial genetic resources, associated genetic and genomic databases, and develop robust bioinformatics tools; 2) develop a basic understanding of the physiology of livestock, poultry, and aquaculture; 3) develop improved understanding of nutritional requirements for animals, particularly in aquaculture and improve the efficiency of nutrient utilization for animals; and 4) develop information, tools, and technologies that can be used to improve animal production systems, all to ensure an abundant, safe, and inexpensive supply of animal products produced in a healthy, competitive, and sustainable animal agriculture sector of the U.S. economy.

PERFORMANCE MEASURE FOR GOAL 4.1

Provide scientific information to maximize the production efficiency of our food animal production systems. Develop new technologies and tools contributing to improved systems to meet current and future food animal production needs of diversified consumers, while ensuring economic and environmental sustainability and animal well-being.

FY 2017 PERFORMANCE REPORT FOR GOAL 4.1 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will identify underlying genetic and/or physiologic mechanisms relating to food animal production and production efficiencies for traits associated with growth physiology, nutrient utilization, reproductive physiology, health, and well-being in food animals.

Accurate estrus detection can improve fertilization timing and sow conception rates, and thereby increase swine production efficiency. Unfortunately, current estrus detection practices, which are based on individual animal behavior, are labor intensive and time consuming. ARS researchers in West Lafayette, Indiana, determined that at the onset of estrus, a sow's body temperature is lower and she becomes more active. Measurement of both temperature and activity can be automated using electronic monitors.

What this means: These data may indicate the initial physiological and behavioral markers of estrus in sows, which can be used in the development of livestock management methods to help producers more easily detect estrus in sow herds.

Rapid growth rate is one of the most important economic traits in rainbow trout that can be improved through selective breeding. ARS researchers in Leetown, West Virginia, selectively bred a pedigreed, commercial-scale rainbow trout population to market weight for five generations. Compared to the control line, body weight in the growth-selected line increased by approximately 12 percent per generation through 13 months of age, resulting in a line that grows to and beyond standard market weight approximately 60 percent faster. The improvement in growth over contemporary commercial lines was consistent when fish were reared in different environments.

What this means: This genetically improved and highly characterized population has been released for commercial propagation.

The number of lambs produced by U.S. ewes every year does not currently meet market demand for weaned lambs. Researchers in Dubois, Idaho, worked with ARS scientists in Clay Center, Nebraska, and researchers at Virginia Tech University and Montana State University to assess the use of more prolific sheep breeds for increasing the number (and therefore the weight) of lambs weaned in range production systems. Researchers demonstrated that using more prolific breeds such as Polypay and Romanov-cross in a rangeland setting yielded more lambs and higher lamb-weight yields than using traditional wool-type breeds. The more prolific breeds produced lower-quality wools and lighter fleeces than wool-type breeds, but the higher total lamb weight compensated for reduced returns from wool sales.

What this means: Results are being used by the U.S. sheep industry to guide producers in selecting breeds and genetics that will increase lambing rates in rangeland production systems.

Indicator 2: During 2017, ARS will develop genomics infrastructure and tools to efficiently identify genes, their function, and interactions with environmental factors for exploitation in genome enabled improvement programs for food animals.

Reference genomes that accurately represent all the genes and regulatory sequences in their correct order and orientation can be used by breeders to develop improved livestock breeds with desirable traits. The reference genome for cattle was published in 2009 and had many inaccuracies and deficiencies, as does the reference genome for pigs, which was published in 2012. To improve the cattle genome sequence, ARS researchers in Clay Center, Nebraska, collaborated with researchers at the University of California, Davis; the University of Missouri, Columbia; the University of Maryland; the National Human Genome Research Institute; and ARS researchers in Beltsville, Maryland, to generate an improved cattle reference assembly 100 times more continuous (a key measure of accuracy and quality) than the existing cattle reference. This new reference assembly more accurately represents the genes related to immune functions, which are notoriously difficult to assemble. For swine, ARS researchers in Clay Center worked in a collaboration led by the Roslin Institute in Scotland and collaborators at two U.S. universities and three genome industry partners to develop an improved reference assembly for swine that is 200 times more continuous than the existing reference, and a second assembly of a crossbred pig that 100 times more continuous than the original reference.

What this means: The new assemblies of the original cow and pig are now the accepted reference genomes for cattle and swine, and the alternate crossbred pig assembly is being used to investigate genome structure and function in commercial pig populations. These improved genomes will facilitate progress on genomic selection in beef cattle and swine.

A high-quality genome sequence is important for facilitating a meaningful understanding of fish biology. ARS researchers in Leetown, West Virginia, worked closely with national and international cooperators to assemble a reliable and high-quality reference genome sequence for rainbow trout. The portion of the new assembly that aligns to chromosome sequences increased from 5 percent to 88 percent, dramatically improving the effectiveness of genomic approaches to selective breeding and gene discovery. The new reference genome is available for browsing through the online interactive databases of the National Center for Biotechnology Information.

What this means: Knowing the rainbow trout genome assembly and chromosome sequences will lead to major improvements in aquaculture genetics and all other aspects of fish quality improvement and fish biology research.

One of the key goals of livestock genetics and genomics research is to discover and use the genetic variants underlying economically important traits such as reproductive performance, feed efficiency, disease resistance/susceptibility, and product quality. However most critical variants are not known. ARS scientists in Clay Center, Nebraska, sequenced the genomes of 72 influential sires and dams of the research unit's swine herd, identified approximately 22 million variants, and submitted them to public databases. By aligning these sequences to the pig genome, researchers found that about 139,000 of these variants were expected to alter or disrupt proteins coded by genes in the genome, or were likely to regulate protein production. Because these variants are likely to alter proteins, they are most likely to have a significant effect on various traits of interest to livestock producers. Five hundred sixty-five variants were classified as high-impact, loss-of-function (LOF) mutations, meaning they render the protein inoperable.

What this means: These LOF variants, along with functional variants likely to influence various reproductive traits, were included in a commercially available genotyping microarray and this information is expected to improve breeding efforts to enhance production traits.

Indicator 3: During 2017, ARS will develop and improve sustainable production systems for food animals; incorporating strategies to optimize production system efficiency while ensuring economic and environmental sustainability.

Methane loss from cattle during the finishing process represents an energy loss that could be used for animal maintenance and growth, and methane is also a greenhouse gas that contributes to global warming to a much greater extent than carbon dioxide. ARS scientists in Clay Center, Nebraska, determined that adding corn oil to the finishing diet reduces livestock methane production and increases the amount of energy the animal retains as fat and carbohydrate instead of protein.

What this means: Supplementing finishing diets with corn oil aids cattle fat and carbohydrate retention while reducing the emission of a greenhouse gas.

Determining optimal environmental parameters for raising Atlantic salmon in water recirculation aquaculture systems is critical to supporting the growth of land-based salmon production in the United States. ARS extramural researchers in Shepherdstown, West Virginia, defined the safe upper limit of nitrate-nitrogen that Atlantic salmon can be exposed to without negative effects on growth performance, survival, or welfare indicators. Nitrate-nitrogen is an end-product of biofiltration that accumulates as the level of water reuse increases. Researchers also identified optimal levels of dissolved oxygen and carbon dioxide and described ideal swimming speeds that produce the best Atlantic salmon performance.

What this means: Collectively, these findings defined acceptable ranges for water quality information needed by producers.

Methane loss from cattle during the finishing process represents an energy loss that could be used for animal maintenance and growth. Methane is also a greenhouse gas and contributes to global warming to a much greater extent than carbon dioxide. An ARS scientist in Clay Center, Nebraska, determined that when steers that were fed more than maintenance levels of food, the greatest methane production occurred 5 to 6 hours after feeding, with a secondary peak in methane production occurring 9 to 11 hours after feeding. When steers were fed a maintenance level of food, there was only one peak in methane production, usually 4 to 7 hours after feeding.

What this means: These differences in methane production after a meal indicate that caution should be exercised when using a single time point measure of methane production and extrapolating it to an estimate of 24-hour methane production.

Indicator 4: During 2017, ARS will characterize nutrient requirements of food animals; measure nutrient availability of traditional and nontraditional feedstuffs; and develop strategies for improving nutrient use efficiency.

Weaning, transport, and thermal stress have the potential to increase disease incidence and reduce growth rates among piglets. To combat these negative effects on piglet health and well-being, management practices have traditionally included adding antibiotics to the diet. However, the 2017 Veterinary Feed Directive now prohibits many dietary antibiotics from being used, which may result in reduced piglet growth and putting the health and welfare of the animals at risk. ARS researchers in West Lafayette, Indiana, performed one laboratory study of piglets housed individually, and another study of piglet in a production environment. In these studies, they compared the use of l-glutamine (an amino acid, fed at 0.2 percent of the diet) as a replacement for traditional dietary antibiotics following piglet weaning and transport. In the laboratory setting, pigs given l-glutamine exhibited an improvement in growth that was similar to improvements after antibiotics were used. In the production setting, piglets that were given either l-glutamine or traditional dietary antibiotics grew faster, ate more, and exhibited a twofold reduction in their requirements for additional therapeutic antibiotic injections, compared with pigs that did not receive antibiotics.

What this means: These data suggest providing l-glutamine at 0.2 percent of the diet following weaning and transport can improve piglet health and well-being in a way that is similar to traditional dietary antibiotic treatments. This information offers swine producers an effective alternative to antibiotics that reduces feed costs by approximately 18 percent on a per ton basis when compared with traditional dietary antibiotics.

Fish oil has been a critical ingredient in feeds for carnivorous fishes, but it continues to increase in price and decrease in availability. ARS scientists and their University of Idaho collaborators in Hagerman, Idaho, evaluated the ability of certain fish species to biosynthesize and convert plant oils to omega-3 fatty acids when reared on feeds free of fish meal and fish oil (i.e., marine free). The researchers used genetic selection procedures to breed these fish, and the animals showed an 11 percent increase in omega-3 fatty acids compared with the previous generation. This strategy raised the fatty acid percentage of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) to 6.61 percent, whereas fish that were fed fish oil typically have 18 percent.

What this means: Continued development of fish strains that do not require fish meal or fish oil and maintain the same health benefits and taste would significantly improve the sustainability and economics of U.S. aquaculture production.

Indicator 5: During 2017, ARS will characterize food animal germplasm for traits of importance and continue to increase the inventory of germplasm stored within the National Animal Germplasm Repository to preserve biodiversity.

ARS has a large and important collection of animal genetic resources, and the stored collection has been used to regenerate or analyze important lost animal genetic resources. For example, Purdue University acquired pig germplasm samples from the stored collection to reconstitute a research line of pigs that was no longer available. The reestablished line had traits known to affect meat quality and were used in a project that garnered substantial funding, generated more than 10 scientific articles, and prompted Virginia Tech University to establish a second research population of this pig line. In another example, the Angus Association obtained a stored semen sample from a prominent bull and determined the bull was free of a lethal mutation, which meant more than 29,000 other cattle did not have to be genotyped, saving the Association approximately $2 million. In a final example, collaborative research between ARS scientists in Fort Collins, Colorado, and researchers at Pennsylvania State University determined there were only two different Y chromosomes (which determines whether an animal is male) in the current U.S. Holstein population (our major milk producing breed) and that there were two additional Y chromosomes in semen stored in the collection that were not identified in the present Holstein population. ARS and Pennsylvania State University scientists worked with industry to produce bull calves with these two lost Y chromosomes from the collection as a first step to re-introducing them to increase genetic diversity.

What this means: These examples demonstrate the value of the germplasm collection to the U.S. livestock sector as a tool for industry and researchers to use in their efforts to solve a range of livestock industry problems.

To maintain the genetic diversity of poultry in the United States, the germ lines of turkey and chicken populations need to remain accessible, but it is not feasible to maintain live populations indefinitely. Storing frozen semen from male poultry would provide a reasonable insurance against loss of genetic diversity, but fertility rates using current methods for freezing semen are not reliable enough to ensure the ability to fertilize eggs and produce new chicks, especially from those poultry lines with inherently low reproductive rates. Poultry sperm is known to lose cholesterol from the plasma membrane after exposure to cold temperature, which may contribute to its poor fertility after freezing and thawing. ARS scientists in Beltsville, Maryland, investigated whether adding different amounts of cholesterol to semen before freezing would improve its fertilizing ability after thawing. Three of the four turkey lines showed an improvement in fertility when cholesterol was used (32.1 percent of eggs fertilized) compared with semen frozen without cholesterol (3.8 percent of eggs fertilized). In addition, 15 percent more live birds were hatched when cholesterol was used during cryopreservation.

What this means: The data indicate that this strategy would result in high enough fertility rates to reconstitute the poultry lines using frozen semen, and semen that has been frozen in this manner could be stored in a germplasm repository for successful future use.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 4.1

During FY 2018, ARS will:

1. Identify underlying genetic and/or physiologic mechanisms relating to food animal production and production efficiencies for traits associated with growth physiology, nutrient utilization, reproductive physiology, health, and well-being in food animals.
2. Develop genomics infrastructure and tools to efficiently identify genes, their function, and interactions with environmental factors for exploitation in genome enabled improvement programs for food animals
3. Develop and improve sustainable production systems for food animals; incorporating strategies to optimize production system efficiency while ensuring economic and environmental sustainability.
4. Characterize nutrient requirements of food animals; measure nutrient availability of traditional and nontraditional feedstuffs; and develop strategies for improving nutrient use efficiency.
5. Characterize food animal germplasm for traits of importance and continue to increase the inventory of germplasm stored within the National Animal Germplasm Repository to preserve biodiversity.

During FY 2019, ARS will:

1. Identify and understand underlying genetic and/or physiologic mechanisms relating to food animal production and production efficiencies for traits associated with growth physiology, reproductive physiology, health, and well-being in food animals and use that information to improve food animal production efficiency.
2. Develop genomics infrastructure and tools to identify genes, their function, and their interactions with environmental factors for exploitation in genome enabled improvement programs for food animals.
3. Develop and improve sustainable production systems for food animals; optimizing strategies to improve production system efficiency while ensuring economic and environmental sustainability.
4. Characterize nutrient requirements of food animals, including mechanisms of nutrient use; measure nutrient availability of traditional and nontraditional feedstuffs; and develop strategies for improving nutrient use efficiency.
5. Characterize food animal germplasm for traits of importance and continue to increase the inventory of germplasm stored within the National Animal Germplasm Repository to preserve biodiversity.

During FY 2020, ARS will:

1. Identify and understand underlying genetic and/or physiologic mechanisms relating to food animal production and production efficiencies for traits associated with growth physiology, reproductive physiology, health, and well-being in food animals and use that information to improve food animal production efficiency.
2. Develop genomics infrastructure and tools to identify genes, their function, and their interactions with environmental factors for exploitation in genome enabled improvement programs for food animals.
3. Develop and improve sustainable production systems for food animals; optimizing strategies to improve production system efficiency while ensuring economic and environmental sustainability.
4. Characterize nutrient requirements of food animals, including mechanisms of nutrient use; measure nutrient availability of traditional and nontraditional feedstuffs; and develop strategies for improving nutrient use efficiency.
5. Characterize food animal germplasm for traits of importance and continue to increase the inventory of germplasm stored within the National Animal Germplasm Repository to preserve biodiversity.

Goal 4.2 - Prevent and Control Pests and Animal Diseases that Pose a Threat to Agriculture, Public Health, and the Well-Being of American Citizens.

NATIONAL PROGRAM 103 - ANIMAL HEALTH

NATIONAL PROGRAM 104 - VETERINARY, MEDICAL AND URBAN ENTOMOLOGY

NATIONAL PROGRAM 106 – AQUACULTURE

Investments in animal protection research are critical to the growth and resilience of the supply of food for tomorrow and Feed the Future initiatives. Enhancing the health of animals in agricultural production systems will directly impact food quality and ensure a sufficient supply of macro and micro-nutrients to meet people's basic needs worldwide. When combined with other investments in agricultural development, research-based innovations will address some of the fundamental constraints that give rise to food insecurity by reducing production risks associated with pests and diseases.

Achieving results in animal protection research in the 21st century will demand a systems biology approach in which knowledge obtained from animal genomes, functional genomics, clinical trials, and epidemiology are integrated in the discovery and development of countermeasures for preventing and controlling disease outbreaks.

Entomological research will concentrate on priority problems affecting animal production, human health, and the well-being of American animals and citizens. The research aims to dedicate 30 percent of resources to basic research that provides relevant information about target pests and 70 percent to applied research and product development. The program seeks to attain a balance of skills among its scientists so that it can take full advantage of the latest developments in biology, while at the same time applying its efforts to solution of practical problems.

Accordingly, the goal of the ARS animal protection research programs is to protect and ensure the safety of the Nation's agriculture and food supply through improved disease detection, prevention, control, and treatment. Basic and applied research approaches will be applied to solve animal health problems of high national priority. Emphasis will be given to methods and procedures to control animal diseases through the discovery and development of:

- Diagnostics and tools for identification of pests/vectors;
- Vaccines;
- Biotherapeutics;
- Pesticides, repellents, attractants, traps, and other innovative products for pest/vector control;
- Animal, pest, and vector genomics applications;
- Disease management systems and integrated pest/vector management systems;
- Animal disease models;
- Farm biosecurity measures;

- Applications of global information systems; and
- Chemical ecology of pests and vectors.

Animal protection national programs have eight strategic objectives:

1. Develop an integrated animal, arthropod, and microbial genomics research program.
2. Launch research programs to provide alternatives to antibiotics in food animal production.
3. Build a technology-driven vaccine and diagnostic discovery research program.
4. Develop core competencies in field epidemiology and predictive biology.
5. Develop expert collaborative research laboratories recognized by the World Organization for Animal Health (OIE) and the United Nation's Food and Agriculture Organization (FAO).
6. Develop a model technology transfer program to achieve the full impact of our research discoveries.
7. Perform the full spectrum of research for improvement of veterinary, public, and military entomology.
8. Develop safe and effective methods for prevention of damage caused by arthropods to homes and households.

PERFORMANCE MEASURE FOR GOAL 4.2

Provide scientific information to protect animals, humans, and property from the negative effects of pests and infectious diseases. Develop and transfer tools to the agricultural community, commercial partners, and government agencies to control or eradicate domestic and exotic diseases and pests that affect animal and human health.

FY 2017 PERFORMANCE REPORT FOR GOAL 4.2 - ACCOMPLISHMENTS

Indicator 1: During 2017, ARS will describe five new discoveries or developments significant for their scientific or applied value.

Enteric septicemia of catfish (ESC) is the one of the most problematic bacterial diseases affecting channel catfish fingerling production in aquaculture. ARS collaborators from Mississippi State University in Stoneville, Mississippi, developed an effective vaccine and delivery method against ESC. To date, approximately 180 million stocked catfish have been orally vaccinated in field trials on commercial farms.

What this means: Improved survival of vaccinated catfish increased the average value of farm production by $1,800-$2,500 per acre.

Vesicular stomatitis virus (VSV) is an animal pathogen spread by insects, and is one of the most common vesicular diseases affecting horses, cattle, and pigs throughout the Americas. There is currently limited understanding of the cause of VSV outbreaks even though VSV has occurred in the United States every decade since 1916. The disease is complex, with ecological, environmental, climatic, and time factors that may contribute to disease outbreaks. Having a better understanding of the cause and progression of VSV could provide a research model for predicting animal disease outbreaks spread by insects and other arthropods. ARS scientists from Colorado, Kansas, New Mexico, New York, and Wyoming collaborated to develop early warning strategies for VSV. Coupling big-data model integration with human and machine learning, ARS scientists evaluated the relative importance of a large and diverse suite of variables to patterns in VSV disease outbreaks. Their findings showed a sequence of early indicators accompanied by the presence of important disease-transmitting insects.

What this means: Before this analysis, little information was available about the different roles insects and environmental factors played in disease outbreaks. These findings about the role of latitude, elevation, and long-term precipitation in disease outbreaks will allow livestock producers or horse owners to monitor local conditions for determining the likelihood that VSV could occur in any month of the year.

Zika, yellow fever, and dengue virus are transmitted by the yellow fever mosquito (*Aedes aegypti*), and Zika virus is one of the newest viruses to be introduced into the United States. Developing a regional strategy to reduce the yellow fever mosquito population is needed to help reduce the spread of these diseases. ARS researchers in Gainesville, Florida, worked with university and local government public health agency collaborators to develop a comprehensive regional program to reduce the population of vectors – insects and other arthropods that carry and transmit disease – including the yellow fever mosquito. ARS researchers led the development of a program that combined traditional vector control, community engagement, and vector surveillance solutions in a unique, innovative way to reduce the risk of Zika virus transmission by reducing or eliminating mosquito populations.

What this means: This system has not yet been adopted, but has contributed significantly to development of new vector control strategies in the United States and partner nation agencies at local, national, and international levels.

Indicator 2: During 2017, ARS will form new partnerships and continue old partnerships with industry, universities, and other government agencies in order to promote production and marketing of new methods for detection and identification of animal pathogens, arthropods that transmit pathogens, and arthropods that destroy property, including genetic markers, new methods of detecting gene sequences or antibodies or proteins, and comprehensive guides to morphological identification.

Foot-and-mouth disease (FMD), a highly contagious disease that affects cattle, pigs, and small ruminants, is considered to be a major global threat to animal agriculture. Although FMD was eradicated from the United States in 1929, its reintroduction could result in billions of dollars in annual lost revenue to U.S. livestock producers. FMD diagnostics and vaccines have been used to control the disease, but significant gaps remain in the availability of effective veterinary medical countermeasures suited for use in the United States. ARS scientists working at the Plum Island Animal Disease Center in Orient Point, New York, have made significant breakthroughs in developing better veterinary countermeasures to detect, prevent, and control FMD should an incursion ever happen in the United States. The first breakthrough is a vaccine platform called the "leaderless" FMDLL3B3D vaccine. The attenuated vaccine has a portion of the viral sequence known as the leader deleted (e.g., leaderless). When injected, this vaccine stimulates the same immune response that is stimulated after vaccination with inactivated FMD vaccines made with virulent wild-type virus strains.

What this means: Unlike current FMD vaccine platforms, the FMDLL3B3D vaccine strains are fully attenuated, and they can be produced safely in the United States without the risk of causing a devastating FMD outbreak if they escape from a manufacturing facility.

The cattle fever tick (*Rhipicephalus microplus)* transmits the disease cattle fever (Babesiosis) to cattle. The genome of the cattle fever tick, which contains more than twice the amount of DNA as the human genome, is difficult to sequence. ARS scientists in Kerrville, Texas, worked with Australian researchers at Murdoch University's Centre for Comparative Genomics and published the genome sequence for this cattle fever tick. They identified genes associated with cattle fever pathogen maintenance, the cattle host immune response, pesticide resistance, tick feeding, and others.

What this means: This new comprehensive sequence information is facilitating tick vaccine research and pesticide resistance monitoring, which will help protect cattle health.

Indicator 3: During 2017, ARS will form new partnerships and continue old partnerships with industry, universities, and other government agencies in order to promote production and marketing of inventions that protect animals from pathogens or manage arthropods that transmit pathogens or damage property.

Because of rising concerns over the development of antibiotic resistance, there is a need to develop protocols for the appropriate use of antibiotics in food animals and viable alternatives for antibiotic use that maintain optimal animal health and performance. Direct-fed microbials (DFMs), often referred to as probiotics, are a potential nonantibiotic replacement that have been studied extensively and used in commercial applications. DFMs are beneficial bacteria often used as feed supplements to promote gut health. To better understand how probiotics enhance gut health in poultry and the mechanisms used by the nonpathogenic probiotic bacteria *Bacillus subtilis*, ARS scientists in Beltsville, Maryland, carried out extensive animal studies to show that certain *Bacillus* strains stimulate innate host immune responses, decrease harmful inflammatory responses, and promote gut integrity when used as a feed additive in young chickens.

What this means: These results provide scientific evidence for the beneficial effects of probiotic bacteria and the potential use of *B. subtilis* as a feed additive to promote gut health in commercial poultry production and reduce the use of medically important antibiotics.

Worldwide tilapia aquaculture is valued at about $8 billion and the U.S. aquaculture industry produces nearly 30 million pounds of tilapia per year. However, production is hindered by two bacteria*, Streptococcus iniae* and *Streptococcus agalactiae*, which are responsible for around $1 billion in annual world-wide losses. ARS scientists in Auburn, Alabama, collaborated with industry partners and verified that tilapia resistance to *S. iniae* infection is heritable and that selective breeding of superior individuals produced increased disease resistance in subsequent generations. They also demonstrated that resistance to *S. agalactiae* was also heritable. Tilapia industry breeding programs now select for resistance to the two *Streptococcus* sp., as well as selecting for increased harvest weights and reduced disease risks in rapidly-growing fish. The improved tilapia are being sold throughout the Americas and abroad.

What this means: Based on current production statistics and available models, representative gains from growing the improved tilapia on an average sized farm adds $635,000 in revenue. This research helps U.S. fish farmers and paves the way globally for reducing antibiotic use on farms, leading to safer products entering the United States.

Fire ants inflict serious and sometimes fatal bites to animals and humans, and they cause billions of dollars of crop damage and other structural damage every year. *Solenopsis invicta* virus 4 (SINV-4) belongs to a new virus family, Polycipiviridae, and viruses within this family appear to infect only ant species. ARS scientists in Gainesville, Florida, discovered SINV-4 in South American fire ant populations and determined that this virus is also present in U.S. fire ant populations.

What this means: Because it is known to infect only ant species, SINV-4 may be a good biocontrol agent for controlling invasive ants, including fire ants. This research is useful to the pest control industry and other industries that are harmed by this pest.

FY 2018-2020 PERFORMANCE PLAN FOR GOAL 4.2

During FY 2018, ARS will:

1. Describe five new discoveries or developments significant for their scientific or applied value.
2. Form new partnerships and continue old partnerships with industry, universities, and other government agencies in order to promote production and marketing of new methods for detection and identification of animal pathogens, arthropods that transmit pathogens, and arthropods that destroy property; including genetic markers, new methods of detecting gene sequences or antibodies or proteins, and comprehensive guides to morphological identification.
3. Form new partnerships and continue old partnerships with industry, universities, and other government agencies in order to promote production and marketing of inventions that protect animals from pathogens or manage arthropods that transmit pathogens or damage property

During FY 2019, ARS will:

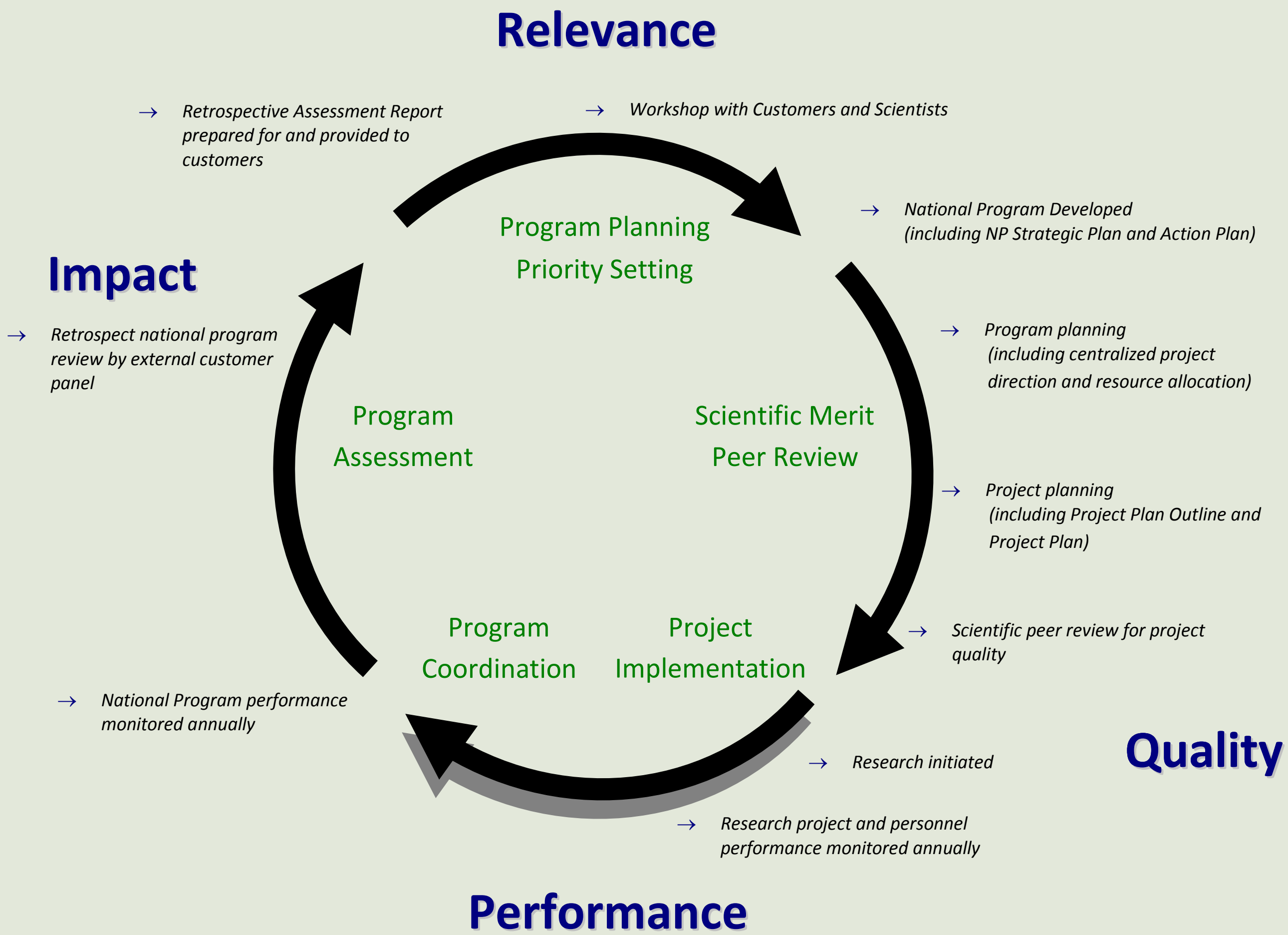
1. Identify five new scientific discoveries that provide scientific information contributing to solving problems of high national priority.
2. Establish strategic public and/or private partnerships that will enable the technology transfer of four ARS inventions.
3. Identify two discoveries that will contribute to the development of new diagnostics for the detection of priority pest and infectious disease agents.
4. Identify two discoveries that will contribute to the development of veterinary medical countermeasures.
5. Form new partnerships and continue old partnerships with industry, universities, and other government agencies in order to promote production and marketing of inventions that protect animals from pathogens or manage arthropods that transmit pathogens or damage property.

During FY 2020, ARS will:

1. Identify five new scientific discoveries that provide scientific information contributing to solving problems of high national priority.
2. Establish strategic public and/or private partnerships that will enable the technology transfer of four ARS inventions.
3. Identify and cultivate intra-agency partnerships that will lead to predictive and mitigation strategies for two arthropod-borne and/or animal diseases.

APPENDIX 1 - NATIONAL RESEARCH PROGRAM MANAGEMENT IN ARS

Approximately 690 research projects from around the country are aligned into 16 National Programs that encompass all the research of the Agency. The National Programs are grouped into four program areas: Animal Production and Protection; Crop Production and Protection; Natural Resources and Sustainable Agricultural Systems; and Nutrition, Food Safety, and Quality. Each of the four program areas is managed by a Deputy Administrator and each program is led by a team of National Program Leaders (NPLs). Some 25 NPLs are responsible for planning and developing research strategies to address critical issues affecting American agriculture. About 200 Research Leaders work with five geographically-based Area Directors to implement the coordinated research objectives issued by the NPLs.



Implementation of the 5-Year National Program Cycle

The overarching objectives of the National Programs are ***relevance, quality,*** and ***impact*** of ARS research, all important elements of improved accountability. Research must be ***relevant*** to the highest priority problems, the goals and outcomes of the research should significantly ***impact*** the problems, and the science must meet the highest standards of ***quality.*** To ensure that these objectives could be achieved, ARS implemented the National Program Cycle, a cycle of phases embodying a series of recurring activities.

The 5-year program management cycle illustrates the activities by which ARS conducts its research: program planning and priority setting, peer review, project implementation, program coordination, and assessment. The cycle ties these activities together in a recurring 5-year sequence to ensure effective and efficient program and project management within ARS.

Ongoing monitoring of project quality and performance takes place throughout the program cycle, and adjustments are made when necessary to improve performance or meet emerging challenges. At the end of the program's 5-year cycle, a rigorous National Program Retrospective Review is convened. The purpose is two-fold: to ensure, based on feedback from an outside group of experts (made up of academics, stakeholders, and government) that the research is being conducted as indicated in the Action Plan, and to gain advice and insight from these same experts as to the future direction of the research.

Relevance, Quality (Prospective and Retrospective), and Performance—these objectives are what a research organization must promote to be successful. Program Planning and Priority Setting, Scientific Merit Peer Review, Project Implementation and Coordination, and Program Assessment prescribe the actions the Agency undertakes carefully, thoroughly, and with outside review to demonstrate that our research is of the highest quality.

Increasing Communication Within and Outside ARS

By definition, the planning and implementation of National Program research is designed to be a participatory process requiring significant input from the broad sources of expertise and experience within and outside the Agency. Through coordinated efforts that emphasize communication with valued partners and scientists, ARS can ensure that public resources are expended in a targeted and synchronized fashion on scientifically and programmatically relevant problems.

Further, by gathering input from outside users of ARS research, the Agency meets the ever-increasing demand for public accountability. ARS solicits input from the Administration, regulatory and action agencies, producers and producer groups, university communities, and non-governmental organizations, often through face-to-face exchanges. By accounting for the needs and priority issues of these customers, stakeholders, and partners, ARS develops responsive research that emphasizes meeting short-term emergencies or requirements, as well as long-term sustained research to address problems of regional, national, and international scope and importance.

Emphasis on communication and coordination ultimately ensures that the physical, financial, and human resources of ARS are deployed appropriately to address high-priority agricultural, food, and environmental research needs of the Nation.

Because agricultural research is not the exclusive domain of any public or private entity, the very specific and the wide variety of needs that farmers, producers, ranchers, and industry stakeholders have must be met in a broad collaborative and cooperative effort. ARS has developed and continues to utilize an extensive network of research relationships among researchers with universities, industry, and other Federal government agencies to meet the research needs of U.S. agriculture. First among those Federal relationships is the USDA National Institute for Food and Agriculture (NIFA), USDA's extramural research agency. ARS and NIFA national program leaders work closely together to ensure that research funded by each agency is complimentary and not duplicative. For example, ARS and NIFA national program leaders have collaborated on utilizing intramural and extramural research to develop joint action strategies for research on plant diseases and pests (i.e., citrus greening), animal diseases, and water and soil conservation.

APPENDIX 2 – INTERNATIONAL COLLABORATIONS BY REGION AND COUNTRY

Collaborations with Countries in Africa - 174

Algeria	1	**Ghana**	11	**Nigeria**	12
Benin	1	**Guinea-Bissau**	1	**Republic of Congo**	1
Burkina Faso	1	**Kenya**	30	**Rwanda**	2
Burundi	1	**Lesotho**	1	**Senegal**	3
Cameroon	2	**Madagascar**	1	**South Africa**	26
Central African Republic	1	**Malawi**	8	**Tanzania**	14
Democratic Republic of the Congo	1	**Mali**	2	**Togo**	1
Egypt	14	**Morocco**	7	**Tunisia**	4
Ethiopia	9	**Mozambique**	5	**Uganda**	8
Gambia	2	**Namibia**	1	**Zambia**	3

Return to Collaborations map.

Collaborations with Countries in Asia - 507

Azerbaijan	1	**Kuwait**	1	**Saudi Arabia**	2
Bangladesh	7	**Laos**	1	**Singapore**	2
Cambodia	2	**Lebanon**	1	**South Korea**	58
China	212	**Malaysia**	4	**Sri Lanka**	2
Georgia	4	**Mongolia**	2	**Syria**	1
Hong Kong	1	**Nepal**	2	**Taiwan**	20
India	22	**Oman**	**1**	**Tajikistan**	2
Indonesia	6	**Pakistan**	20	**Thailand**	15
Israel	28	**Palestinian Territories**	1	**Turkey**	20
Japan	23	**Philippines**	14	**Uzbekistan**	5
Jordan	3	**Russia**	14	**Vietnam**	4
Kazakhstan	6				

Return to Collaborations map.

Collaborations with Countries in Central and South America - 258

Argentina	32	**Costa Rica**	16	**Nicaragua**	1
Bolivia	2	**Ecuador**	6	**Panama**	4
Brazil	127	**El Salvador**	1	**Paraguay**	2
Chile	13	**Guatemala**	4	**Peru**	14
Colombia	18	**Honduras**	5	**Uruguay**	13

Return to Collaborations map.

Collaborations with Countries in Europe - 663

Albania	1	**Hungary**	5	**Portugal**	5
Austria	18	**Ireland**	16	**Romania**	5
Belgium	24	**Italy**	86	**Serbia**	5
Bulgaria	2	**Latvia**	1	**Slovakia**	4
Cyprus	1	**Lithuania**	2	**Slovenia**	1
Czech Republic	8	**Luxembourg**	2	**Spain**	70
Denmark	23	**Moldova**	1	**Sweden**	20
Finland	9	**Netherlands**	40	**Switzerland**	25
France	74	**Norway**	11	**Ukraine**	4
Germany	68	**Poland**	15	**United Kingdom**	102
Greece	15				

Return to Collaborations map.

Collaborations with Countries in North America -186

British West Indies	1	**Jamaica**	2	**Netherlands Antilles**	1
Canada	119	**Mexico**	60	**Trinidad and Tobago**	1
Haiti	2				

Return to Collaborations map.

Collaborations with Countries in Oceania - 104

Australia	75	**New Zealand**	27	**Papua New Guinea**	1
New Caledonia (France)	1				

Return to Collaborations map.