United States Department of Agriculture

AGRICULTURAL RESEARCH SERVICE
2016 ANNUAL REPORT ON SCIENCE

RESEARCH TO DEVELOP AND TRANSFER SOLUTIONS TO AGRICULTURAL PROBLEMS

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ABSTRACT

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This publication is the Agricultural Research Service's 2016 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 2017.

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

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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.

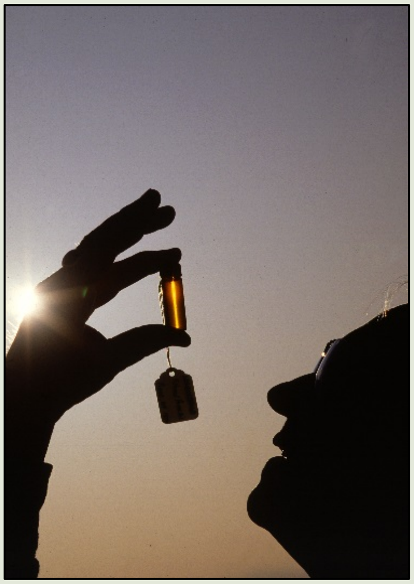
ARS organizes its research activities into 17 National Programs that are part of one of four broad Strategic Goal Areas:

- 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) 2016 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 2017-2019.

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 which ARS releases into the public domain and some of which requires intellectual property protection and licenses as incentive 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.

However, any measure of successful ARS research would have to include the 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 2016 are documented for each of ARS research goals.

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 2016

Scientific Knowledge	3,851 Peer-reviewed journal articles
Knowledge Transfer	59 Trade journal publications 440 Outreach activities 133 New Material Transfer Research Agreements 539 New outgoing Material Transfer Agreements 44 New Cooperative Research and Development Agreements 91 Patent applications filed, 53 new patents issued 29 New licenses, total of 419 active licenses

Progress on Emerging Priorities in FY 2016

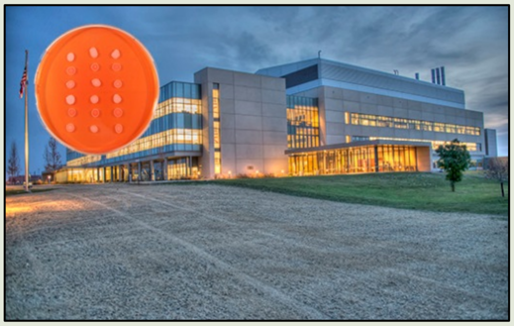
Agriculture is dynamic, driven by environmental, biological, economic, social, and technological change. New capabilities are realized and new threats emerge. In FY 2015, ARS initiated or continued progress on the following emerging priorities.

ARS GRAND CHALLENGE 20/20/25

In FY 2015, ARS set an aspirational goal for itself—to **Transform Agriculture to Deliver a 20 Percent Increase in Quality Food Availability at 20 Percent Lower Environmental Impact by 2025**. This Grand Challenge recognizes not only the many pressing issues facing U.S. agriculture, but that these issues are intertwined. In the minds of the farmer, the consumer, and the citizen, having sufficient food to meet a growing population, ensuring it is of wholesome quality, and addressing the substantial environmental footprint of agriculture are inextricably linked. Recognizing that these issues need to be addressed holistically and synergistically, ARS research leadership developed this Grand Challenge to encourage and facilitate collaboration across projects, locations, and the Office of National Programs (ONP) in utilizing a systems approach to address the agricultural research needs of the nation and the world.

In FY 2016, ARS conducted a Grand Challenge Summit that brought together field scientists, Area Directors, and headquarters leadership to exchange ideas and draft an Implementation Plan. The National Program Leader Grand Challenge leadership team reviewed and revised the draft implementation plan. The leadership team also identified recent and on-going research efforts utilizing a multi-disciplinary, multi-location process similar to what is envisioned for the Grand Challenge. An Executive Committee, including one representative each from ONP, Area Offices, and field scientists, was formed, as was a larger Leadership Council, staffed with representatives from field scientists, Area leadership, and key headquarters offices. This Council is charged with removing barriers to implementing the Grand Challenge, monitoring progress, and fostering internal and external communications.

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.
5. Improve international collaboration and capacities.

In FY 2016, ARS examined the impact of potentially resistant bacteria from livestock transferred into municipal waste streams, waters discharged from municipal wastewater treatment facilities, cattle feedlot runoff catchment ponds, and swine waste lagoons. The study concluded that antimicrobial resistance is a very widespread phenomenon. While antimicrobial resistance was found in cattle, swine, and human waste streams, the higher diversity in resistance was found in human waste streams.

In FY 2016, ARS developed a method for identifying seven different antibiotic resistance genes (for example the gene coding for resistance to the antibiotic Azithromycin). The method was successfully used to screen more than 2,000 bacterial isolates from cattle, and revealed subpopulations of bacteria containing antibiotic resistance genes not previously seen in these animals.

CLIMATE CHANGE

The USDA Climate Change Science Plan has the vision that farmers, foresters, ranchers, land owners, resource managers, policy-makers, and Federal agencies are empowered with science-based knowledge to manage the risks, challenges, and opportunities of climate change and positioned to reduce emissions of atmospheric greenhouse gases and enhance carbon sequestration.

In FY 2016, ARS scientists:

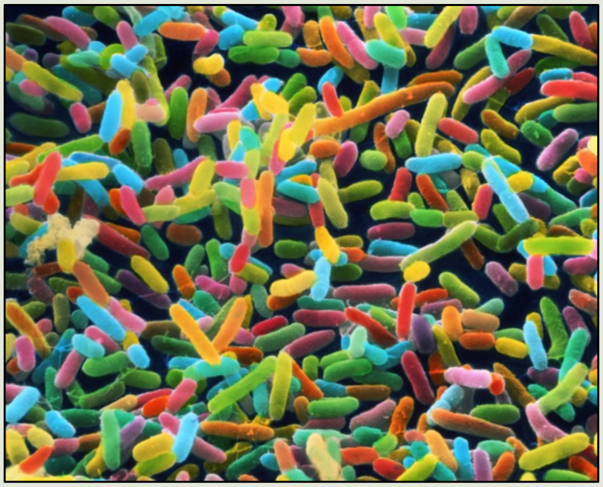
1. Developed or enhanced technologies and management systems that reduce emissions of nitrous oxide, carbon dioxide, and methane.
2. Developed or enhanced technologies and management systems that increase the sequestration of atmospheric carbon, storing more carbon in soils, biomass, and bio-based products.
3. Improved management systems that build soil health and climate resiliency, helping landowners to adapt to weather extremes and changing climatic conditions.
4. Provided data that improves our ability to quantify and inventory our national GHG emissions and carbon storage.

One specific example is the collaborative effort of ARS scientists from more than 30 locations through the Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet). These scientists provided data critical to improving the USDA and USEPA National GHG Inventory Reports, and provided the data and information that numerous stakeholders utilized in developing sustainability goals and GHG reduction targets. The work of this network helped quantify the soil health and GHG benefits of improved crop rotations, the use of cover crops, and the value of reduced tillage. A related effort (Resilient Economic Agricultural Practices; REAP) demonstrated that improved management can lead to the ability to harvest residue for bio-energy production without negatively impacting soil carbon and soil health. This effort led to the launching of a $9 million collaborative U.S. Department of Energy (DOE) grant on sustainable landscape design in which ARS REAP scientists are partnering.

Another example is work by ARS scientists on the capture and utilization of nutrients from livestock manure. New technologies in this area are helping to reduce odor, reduce emissions of nitrous oxide, and provide marketable organic fertilizer products. One technology, called Annamox, that utilizes bacteria to break down ammonia and harvest the ammonia nitrogen from wastewater is being tested for use by NASA for waste management on future manned space missions.

ARS scientists also demonstrated that increasing soil carbon storage improves soil health and the resilience of cropping systems. By improving resilience, a land manager can reduce the negative impacts of extreme events, such as drought, and shorten recovery time. ARS also expanded the Long-Term Agroecosystem Research network (LTAR). LTAR is an 18-location effort to look at all aspects of the production system and evaluate the sustainability of business-as-usual systems currently in use, and to enable greater sustainability via the development of new systems targeted at increasing production, improving producer economic viability, enhancing the environment, and improving the quality of life for rural populations and society as a whole. During 2016, data collection and data management for the network were greatly enhanced, and research projects were refined and better focused on sustainability. Insights gained from the LTAR will enable producers across the country to adapt to changing weather and climate conditions, thus ensuring continued production and the delivery of ecosystem services well into the future.

MICROBIOME



The White House Office of Science and Technology Policy (OSTP) announced a new National Microbiome Initiative (NMI) on May 13, 2016, to foster integrated study of microbiomes across different ecosystems.

Microbiomes are communities of microorganisms that live on or in people, plants, animals, soil, oceans, and the atmosphere. Microbiomes maintain healthy function of these diverse ecosystems, influencing human health, climate change, food security, and other factors. Dysfunctional microbiomes are associated with issues including human chronic diseases, such as obesity, diabetes, and asthma; local ecological disruptions, such as the hypoxic zone in the Gulf of Mexico; and reductions in agricultural productivity. Numerous industrial processes, such as biofuel production and food processing, depend on healthy microbial communities. Although new technologies have enabled exciting discoveries about the importance of microbiomes, scientists still lack the knowledge and tools to manage microbiomes in a manner that prevents dysfunction or restores healthy function.

In FY 2016, ARS co-chaired the National Science and Technology Council's Fast Track Action Committee on Mapping the Microbiome (FTAC-MM). The FTAC-MM inventoried Federal microbiome research and made recommendations for Federal investments to target identified areas of need, including computational biology and bioinformatics, reference databases and biorepositories, standardized protocols, and high-throughput tools, as well as more longitudinal and functional studies and interdisciplinary research. ARS now co-chairs the successor to FTAC-MM, the Microbiome Interagency Working Group (MIWG), which is developing a Federal Strategic Research Plan for Microbiome Research.

Salmonella affects more than 1.4 million people in the United States each year, resulting in about 15,000 hospitalizations and 400 deaths. ARS researchers are studying the development of the chick microbiome from hatching to 28 days, including the role of prebiotics and vaccination on the persistence of *Salmonella*. These studies found that both vaccination and prebiotic use (microbial nutrients) in the chick diet reduce the persistence of *Salmonella* in the challenged birds. Similar approaches with other poultry and livestock may help to reduce other food-borne diseases

Disease-suppressive soils provide microbiome-mediated protection of crop plants against infections by soil-borne pathogens and pests, which include plant pathogenic fungi, fungal-like oomycetes, bacteria, nematodes, and parasitic weeds. Specific successful suppression techniques require time for a pathogen reaction to develop, is likely to be pathogen specific, and establishes a pathogen memory in the soil microbiome analogous to the adaptive immune response in animals. Mechanistic understanding of the plant metabolites and pathogen effectors that trigger the adaptive immune response of soil microbiomes provides a means to engineer better soils for agriculture.

The manipulation of the crop microbiome can improve environmental stress tolerance and suppress disease during crop production. However, current microbial DNA sequence datasets are often extremely large and complex and powerful new computational tools are needed for performing core microbiome analyses. In 2016, ARS developed a Web-based tool that is easy to use for analyzing the core microbiome.

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 crop wild relatives 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 its related sciences. NAL maintains collections of agricultural books and journals, but 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, use and management of water resources, pest management, plant and animal growth, and research calculations.

AGRICULTURAL RESOURCES AND RESEARCH TOOLS – 2016 ACCOMPLISHMENTS

ARS scientists who produce the National Nutrient Database for Standard Reference added, through a public-private partnership, the nutrient composition of more than 80,000 brand name food products to the database. This new information on specific brand name products was supplied by food manufacturers and will increase the accuracy of assessing what Americans eat, since the database previously only calculated generic averages for each type of food.

ARS software developers and plant germplasm curators in Beltsville, Maryland, and Ames, Iowa, completed the first major update in 20 years for the Germplasm Resources Information Network (GRIN), the global standard for managing and delivering information associated with plant germplasm. The new "GRIN-Global" plant germplasm information management system was implemented in 2015 in the U.S. National Plant Germplasm System (comprising 19 ARS genebanks) and adopted by six international genebank systems. During 2016, GRIN-Global provided breeders and researchers with access to key descriptions for plant germplasm via more than 1.5 million individual Web page visits, and facilitated distribution of more than 240,000 plant germplasm samples domestically and internationally. Collectively, this distribution of germplasm and associated information constitutes a technology package that continues to support and strengthen crop breeding and research in the United States and internationally.

The Rangeland Hydrology and Erosion Model is designed to provide sound, science-based technology to model and predict runoff and erosion rates on rangelands and to assist in assessing rangeland conservation practice effects. In 2016, ARS scientists developed a framework and methodology for integration of key ecohydrologic data and relationships, improvements to a Web tool interface, and development of a user training course.

ARS scientists released food and nutrient intake data from 2013-2014 in the What We Eat in America portion of the National Health and Nutrition Examination Survey, conducted as a partnership with the Centers for Disease Control and Prevention. Documentation of intake of foods and their nutrients at different eating occasions and by location of consumption give a detailed picture of what Americans eat.

Prior to development of the genomics component of the Animal-GRIN, the livestock research community did not have a mechanism to permanently store genotypes derived from publically funded livestock genomics work. As a result, the long-term security of expensive data was at risk and it was difficult for other researchers to access and leverage this information in other experiments. An ARS-led team developed a genomics component as part of Animal-GRIN Version 2. With this component, it is possible for public sector researchers to enter their genomic data into the database and for the community at large to have access to those genotypes. The developed component also makes available, for the first time, the linkage and access to genomic, phenotypic, management, and environmental information complete with a physical tissue sample from the individual animal.

The Porcine Translational Research Database contains functional information on 12,125 genes commonly studied in humans, pigs, and rodents. The database is a unique porcine database because it links gene expression to gene function and identification of related gene pathways. The database was updated in 2016 with the addition of genes involved in porcine development and in the production of mucin and collagen.

The Water Erosion Prediction Project (WEPP) is a computer program that predicts soil erosion by water at the field scale. In 2016, ARS developed user training resources for the WEPP model and worked with the USDA Natural Resources Conservation Service on a plan to utilize the model at all of its field offices across the United States.

myPhyloDB is a new Web-based local server that provides an easy-to-use graphical interface for storing metagenomics data in a SQL database and allowing users to standardize, normalize, and analyze DNA sequence and associated data from multiple projects. It provides DNA sequence processing capabilities that are not available on other DNA data platforms.

Long-Term Agroecosystem Research Data Overview, hosted by National Agricultural Library, was expanded with real-time data from additional LTAR locations available via the Web portal. Web sites were developed that included tools to help: 1) producers select cover crops to meet their management needs; 2) producers explore how different lease agreements impact their operation based on production expenses and price and yield data, and 3) the scientific community quickly and easily locate knowledge in scientific literature relevant to specific study locations using a map-based search engine for scholarly publications.

The data generated by U.S. maize and rice geneticists is expanding rapidly, as is the demand for bioinformatic tools that enable researchers and breeders to utilize this knowledge. ARS scientists in Ames, Iowa, and Stuttgart, Arkansas, developed new bioinformatic tools to accelerate maize and rice breeding and research. First, the MaizeGDB Genotype Visualization Tool, developed in Ames, enables maize researchers to survey the genomes of 17,000 maize lines and display all DNA differences in any region of their respective genomes. The MaizeGDB Pedigree Viewer enables breeders to visualize pedigree relationships between maize germplasm lines and identify the best lines genetically as parents for crossing. Combined with knowledge of maize genome functional variation in MaizeGDB, these tools enable breeders to select maize lines to cross to improve germplasm for researchers and farmers. For rice breeders, ARS scientists in Stuttgart created Ricebase, a new database that integrates rice genetic variation, pedigrees, and whole-genome-based data, thus accelerating the discovery and design of molecular markers for marker-assisted breeding and selection, thereby enabling rice breeders to make their selections more efficiently.

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 1,789 foreign research collaborations with 113 countries (shaded in blue) in 2016:

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 2016 PERFORMANCE REPORT FOR GOAL 1.1

Indicator 1: During 2016, ARS will survey, release data on, and analyze national food consumption patterns of Americans.

Accomplishments

One of the gaps in dietary recommendations is the lack of science for dietary advice aimed at children under 24 months of age. The U.S. Government is committed to adding this age group to the dietary guidelines, so researchers from the ARS Children's Nutrition Research Center in Houston, Texas, collaborated with investigators at Deakin University in Australia to analyze dietary intake reported by mothers for 2,740 infants and toddlers in a U.S. national survey taken from 2005 to 2012. In children younger than 1 year, infant formulas and baby foods were the leading source of calories and nutrients. In children aged 12 to 24 months, milk, 100 percent juice, and grain-based mixed dishes were important sources of calories and nutrients, but a number of foods contributing to energy intake had low nutritional quality, including sweet bakery products, sugar-sweetened beverages, and savory snacks. Non-flavored milk and ready-to-eat cereals were the most important contributors to micronutrient intakes.

What this means: These data will help formulate future recommendations for this age group.

What We Eat in America (WWEIA) is the nutrition portion of the National Health and Nutrition Examination Survey (NHANES) conducted in partnership with the Centers for Disease Control and Prevention. In 2016, ARS scientists at the Beltsville Human Nutrition Research Center released food and nutrient consumption data for 2013–2014 in 56 publicly available tables. They also released the WWEIA Food Categories, which classifies more than 8,000 foods and beverages in the USDA food composition database into 152 categories. Thousands of scientific papers have been published over the years linking food consumption to nutrient status and health. NHANES is the only nationally representative survey of its kind and provides snapshots over time of the nutritional status of the American people.

What this means: Snapshots of the nation's food consumption tell us what foods are being consumed, the nutrients contained in those foods, and how they are associated with weight, prevalence of disease, and nutritional status. These determine immunity, inflammation, and risk factors for heart disease. Most food purchased in grocery stores are brand names products and these can have very different nutrient content; having brand name items in the database provides a much more accurate picture of nutrient intake.

Indicator 2: During 2016, 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.

The National Nutrient Database, maintained by ARS in Beltsville, Maryland, contains information on the chemical composition of commonly consumed foods. However, although as many as 500,000 foods may be available in the U.S. food supply and more than 30,000 items are carried in the typical grocery store, until recently, the database contained information on fewer than 9,000 individual items. A public-private partnership among ARS, the North American branch of the International Life Sciences Institute, 1World Sync, and Label Insight brought nutritional label information of nearly 90,000 additional foods to the database.

What this means: This addition will strengthen the ability of USDA and other Federal health agencies to more accurately monitor the food supply and to estimate nutrient consumption by consumers.

Flavonoids are common plant compounds that may be beneficial to human health. A first step in determining whether flavonoids might have health effects is to identify the amounts and types of flavonoids in various plants. Scientists use a technique called liquid chromatography-mass spectrometry to analyze plants, but this method yields thousands of potential but unidentified compounds. Results obtained by this method can take an expert weeks to analyze. ARS researchers in Beltsville, Maryland, have developed an expert, first-of-its-kind, computer program, "FlavonQ," to automate the identification and measurement of three different classes of flavonoids (flavonols, flavones, and proanthocyanidins). The FlavonQ software has reduced the data analysis time for these complex analyses from weeks to hours.

What this means: This expert system will allow rapid population of the USDA nutrient database with data for these flavonoids and facilitate investigation of their effects on human health.

Indicator 3: During 2016, ARS will identify dietary and lifestyle intervention strategies to prevent obesity and promote healthy food choices and eating behaviors.

Excess weight gain during pregnancy leads to adverse outcomes for both mothers and infants. There has been ongoing debate whether excess gestational weight gain is the result of increased consumption or adaptive changes in energy expenditure during pregnancy. An analysis by ARS-supported scientists in Houston, Texas, and collaborators from Baylor College of Medicine, obtained measurements of these factors before conception and at three time points during pregnancy from 45 women. One-quarter of women gained excess weight and ate 750 calories more per day than those who gained ideal amounts of weight. All the women exhibited decreased energy expenditure in physical activity during pregnancy, but there was no difference by weight gain.

What this means: Future interventions for weight gain during pregnancy may be more effective if pregnant women focused solely on limiting their energy intake while increasing the nutrient density of their diet.

Indicator 4: During 2016, ARS will determine the functions, bioavailability, interactions, and requirements for known, emerging, and new classes of nutrients across the lifecycle.

The U.S. Dietary Guidelines urge limited intake of saturated fat because epidemiological data suggest it is associated with cardiovascular disease. However, results from previous human studies indicate this may not always be true. Consequently, ARS researchers at the Western Regional Research Center, in Albany, California, examined the effect of a high-saturated-fat meal on inflammatory markers in obese men and women for 6 hours following the meal. Two different forms of saturated fat (palm oil and whipping cream) were ingested with and without the addition of milk fat globule membrane (MFGM). MFGM surrounds the fat globules in milk and has been shown to reduce inflammation associated with some foods. ARS researchers found that consumption of MFGM with either palm oil or whipping cream resulted in lower total cholesterol, LDL cholesterol, insulin, and small molecules associated with inflammation.

What this means: This suggests that the addition of MFGM ameliorates the negative effect of a high-saturated-fat meal in overweight and obese men and women.

ARS-funded researchers and Tufts University collaborators examined changes over a 3-year period in muscle mass, strength, power, and physical performance among older adults and mobility-limited older subjects. They found that declining muscle function (strength and power) is an independent contributing factor, not just to falling, but to increased fear of falling and to deteriorations in quality of life.

What this means: These findings reinforce the importance of preserving muscle health with advancing age to reduce fall risk and improve quality of life.

Indicator 5: During 2016, ARS will publish new findings on metabolic processes that are affected by nutrient intake.

Use of the glycemic index remains controversial. Although some health organizations and a few countries promote use of the glycemic index for dietary recommendations, the USDA/HHS Dietary Guidelines for Americans do not. Only limited data exist on variability between and within individuals and sources of that variability. ARS-supported researchers and Tufts University collaborators examined these factors in 63 healthy adult volunteers. Using white bread as the standard glycemic index food, scientists found variation between people was 20 percent, but within the same person, repeated measures varied 25 percent, which indicates too large a difference to be useful or reproducible. Blood measures of insulin and glucose status together explained almost one-third of that variability. In another study of 91 obese adults who ate reduced-calorie diets with either high or moderate total carbohydrate levels and high or low glycemic index for 17 weeks, researchers found no effect of any diet on weight loss, fat loss, resting metabolic rate, or metabolic adaptation.

What this means: These results demonstrate that the glycemic index is unlikely to be useful for guiding food choices in people.

Calorie restriction slows aging and cancer growth in many animal species, but its relevance to humans is unknown. Inflammation is now deemed a major contributor to chronic diseases, including heart disease and cancer. ARS-supported scientists in Boston, Massachusetts, collaborated with colleagues at several other institutions to directly study this question by assigning 143 healthy, nonobese adults to calorie restriction and 75 to continue their usual intake for 2 years. Calorie restriction led to a 10 percent weight loss and a reduction in circulating inflammatory markers, and total white blood cell and lymphocyte counts. Long-term calorie restriction was associated with reductions in C-reactive protein and tumor necrosis factor-alpha by 40 percent and 50 percent, respectively; both of these markers are associated with increased heart disease, cancer, and other chronic health problems. Calorie restriction had no effect on the immune response as measured by antibody response to vaccines and delayed-type hypersensitivity responses in the skin. Long-term calorie restriction appears to improve the health of young to middle-aged adults and may decrease risk of major chronic diseases.

What this means: Long-term calorie restriction appears to improve the health of young to middle-aged adults and may decrease risk of major chronic diseases.

It is generally accepted that industrially produced trans fatty acids (TFA) found in partially hydrogenated oils lower beneficial HDL cholesterol and raise harmful LDL cholesterol, but no studies had ever directly examined the effects of consuming naturally occurring TFA from ruminant animals. ARS scientists in Beltsville, Maryland, conducted a feeding trial in 106 healthy adult volunteers who ate either 3 percent industrial TFA, 3 percent ruminant TFA, or 1 percent conjugated linoleic acid (CLA, another naturally occurring TFA, but with a different chemical structure) for 24 days each. Both types of TFA raised LDL cholesterol levels in the volunteers, and ruminant TFA also raised HDL cholesterol levels, whereas CLA led to lower triglyceride levels and had no effect on other lipids.

What this means: These results support the current labeling guidelines from the Food Safety Inspection Service and the Food and Drug Administration.

Indicator 6: During 2016, ARS will discover genetic or epigenetic factors that influence physiologic responses to diet or changes in gene expression in response to dietary intake.

Although the mouse is the most widely used laboratory animal model for human immunity, many discoveries from them do not translate to humans. ARS researchers at the Beltsville Human Nutrition Research Center compared part of the innate immune system (known as the inflammasome) in humans, mice, and pigs. Among 11 gene families that control the inflammasome, 9 were similar in humans and pigs but only 3 were similar in humans and mice. Confirming this observation, inflammatory cell responses in pigs were closer to those of humans than were cells from mice.

What this means: This work supports using swine to model both human immunological and inflammatory responses to infection, as long as the noted differences are kept in mind.

Indicator 7: During 2016, ARS will identify processes and methods whereby agriculture production influences the nutritional value of the food supply.

Dry beans are an important dietary source of many minerals, especially in areas where food is insecure. It may be possible to supply dietary iron through dry beans, but iron bioavailability is low in many varieties, and the reasons for low bioavailability are unclear. Approximately 80 percent of the iron in beans is found in a portion of the bean called the cotyledon, where cells are rich in protein and phytic acid. ARS researchers in Ithaca, New York, with collaborators from Cornell University, found that cotyledon cell walls are not softened or rendered nutritionally useful by cooking and are highly resistant to digestion in the upper intestine, which is the major site of iron absorption. This makes a major portion of bean iron unavailable for absorption until it reaches an area of the intestine where microbes can digest the cotyledon cell walls. However, the latter portions of the intestine do not have much capacity for iron absorption. Moreover, release of the iron is affected by distribution of iron in the seed or coat, and the presence of inhibitors of absorption, including dietary fiber and pigments, in the beans.

What this means: These findings will help with development of bean breeding and processing strategies that can improve beans as a source of iron.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 1.1

During FY 2017, 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 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.

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 2016 PERFORMANCE REPORT FOR GOAL 1.2 - ACCOMPLISHMENTS

Indicator 1: During 2016, 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.

Breeding chickens resistant to *Salmonella* and *Campylobacter* infection is considered, along with vaccination, to be a potential long-term intervention in controlling these bacteria in broiler chicken production. New approaches are needed to produce live poultry that are not colonized by these harmful bacteria, which would translate into pathogen-free meat products for human consumption. ARS researchers in College Station, Texas, have identified a population of roosters from the Athens Canadian Random Bred (ACRB) lineage, a 1950s meat-type chicken, with differential expression of key immune markers to serve as sires for the generation of a F1 population of chickens selected for a more efficient innate immune responsiveness. ARS is attempting to breed chickens with natural resistance to *Salmonella* and *Campylobacter* by using older original chicken populations with greater genetic diversity to produce more pathogen-resistant broilers.

What this means: Development of microbial pathogen-resistant birds would be a dramatic success in enhancing the microbial safety of poultry meat products reaching the consumer.

Enterohemorrhagic *E. coli* (EHEC), also known as STEC (Shiga-toxin producing *E. coli*), are the cause of serious foodborne illness, chronic sequelae, and deaths in the United States. The most well-known of these types of bacteria is *E. coli* O157:H7, but six additional pathogenic *E. coli* strains are of concern to regulatory agencies, including the USDA Food Safety and Inspection Service, and cause severe disease in humans. EHEC can be found in most groups of cattle, but it is not known whether any are specific to culled dairy cows harvested for beef. ARS scientists from Clay Center Nebraska, and Wyndmoor, Pennsylvania, and colleagues belonging to the STEC-CAP research group (a consortium project funded by the USDA National Institute of Food and Agriculture) examined matched fecal, hide, and pre-intervention carcass samples collected from culled dairy cows at harvest. Culture isolation found EHEC in 6.5 percent of feces samples, 15.6 percent of hide samples, and 1 percent of carcass samples. It was concluded that EHEC are common on the hides of culled dairy cattle, and that feces are an important source of EHEC contamination of hides. This information has been transferred to the cattle industry through various industry partners, including the North American Meat Institute, National Beef Association, American Beef Association, and the USDA Food Safety Inspection Service.

What this means: This information is critically important for the epidemiologist, regulatory monitoring of animals, and development of both pre- and post-harvest interventions.

The poultry and animal industries continue to combat the spread of foodborne pathogens in food products and have spent millions of dollars attempting to control *Salmonella* and *Campylobacter* with minimal results. Until recently, the focus has largely been on implementing management strategies for reducing the movement of bacteria from the poultry house environment. Because of increasing cost of new bedding materials, modern broiler producers utilize the same litter for growing out multiple flocks. ARS researchers in College Station, Texas, assessed the changes in bacteria and dispersion of several litter practices in a commercial broiler house. The results demonstrate that better clean-out practices have the potential to reduce contaminant buildup of many chemical pollutants in the litter within the broiler production facility, such as nitrates and heavy metals, including iron, manganese, and zinc. The research also established that proper disposal of litter is necessary for environmental health.

What this means: This study provides an understanding for poultry producers of the role in food safety, as well as animal health, of litter management approaches and their impact on the environment. This is a critical issue for producers since contaminated flocks are subject to closer inspection by USDA regulatory agencies.

Indicator 2: During 2016, 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.

Current metrics used by the California Leafy Greens Marketing Agreements (LGMA) for leafy greens to ascertain the microbial safety of fresh produce required reevaluation. ARS scientists in Beltsville, Maryland, examined the 60-day interval between flooding of fields and replanting of crops, and the 30-foot "no harvest" zone from the edge of the flood currently employed to prevent fecal contamination of crops. In intentionally flooded spinach fields with a negative 5 percent slope, *Escherichia coli* populations were found to decline more slowly in fall trials than in spring trials, and *E. coli* in soils and on spinach plants were detected 30 feet from the edge of the flood.

What this means: These results suggest that LGMA metrics should be revised to include considerations of field and weather conditions that may promote bacterial movement and survival.

Indicator 3: During 2016, 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.

Salmonella can be transmitted to humans through the consumption of contaminated foods, including poultry. Contamination of raw poultry products occurs during live animal production and slaughter operations. The USDA Food Safety Inspection Service (FSIS) monitors contamination of poultry through a testing program to protect consumers. ARS demonstrated that the current FSIS protocol for *Salmonella* testing of whole chicken carcasses may potentially lead to carry-over of intervention solutions, which are used to reduce pathogens in poultry processing, into the collection broth tested by FSIS inspectors. This carry-over could result in underestimating *Salmonella* levels in poultry processing operations. ARS scientists in Athens, Georgia, developed a modified collection broth capable of neutralizing a wide range of sanitizers, and which resulted in a statistically more accurate reporting of Salmonella in poultry processing. FSIS subsequently validated and approved this new modified collection broth for regulatory sampling. In July 2016, FSIS field inspectors implemented the new protocol in their collection of samples for *Salmonella* testing.

What this means: This new protocol now provides a statistically more accurate test and reporting of *Salmonella* levels in poultry, making for a safer food for consumers.

Poultry farmers and regulatory agencies use candling, where a bright light source is used to show details within the egg shell, to learn which eggs are fertile and will hatch into chicks, and for maintaining quality assurance purposes. The official graders with the USDA Agricultural Marketing Service (AMS) were concerned that the current light source was not accurate enough and thus requested ARS to develop a new light source for candling. ARS scientists from Athens, Georgia, designed and developed prototypes of a high-intensity light emitting diode (LED) white light for candling eggs. Both a portable battery-powered model and a stationary model were created. A material transfer agreement was used to complete the design and to transfer the technology to a U.S. commercial partner. The company has now completed the second prototype revision and started selling the lights to the public. AMS has plans to purchase several hundred of these lights to replace all of their existing obsolete candling lights.

What this means: This new LED light source provided greater accuracy for the AMS, which is now replacing all existing obsolete candling lights with this new technology.

Rapid detection of the foodborne pathogen *Escherichia coli* O157:H7 is of vital importance for public health worldwide. ARS-funded scientists at the Center for Food Safety Engineering at Purdue University in West Lafayette, Indiana, have modified a bacteriophage (bacterial virus) specific for *E. coli* O157:H7 by adding a gene from a bioluminescent shrimp that causes the live cells of the pathogenic *E. coli* to glow after bacteriophage infection. This diagnostic tool is very specific and very sensitive, detecting as little as five cells of the pathogen less than 7 hours after culture enrichment. The method also has potential for direct detection of higher pathogen concentrations directly in ground beef. The process uses very low concentrations of bacteriophage and can be integrated into current laboratory protocols. The technology was patented and licensed to a startup company based in Indiana that, based on the potential of this technology, was awarded State funding for capitalization and initial startup costs to assist in its commercial development.

What this means: The coupling of low bacteriophage concentrations and the ease of integration into current protocols provide a low-cost method for the detection of *E. coli* O157:H7 with the potential to improve pathogen surveillance and provide for a safer food supply.

Indicator 4: During 2016, 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.

Containers are used for fruits and vegetables in the field and storage, for produce display in stores, and during transportation; however, they can be easily contaminated with foodborne pathogens. When a contaminated container is in contact with food, pathogens transfer from the container to the food, hence, the importance of having a pathogen-free container. ARS researchers in Wyndmoor, Pennsylvania, developed methods and coating formulas to produce food containers with an antimicrobial surface. Specifically, the scientists used titanium dioxide (TiO2) nanopowders, which are ingredients in food coloring, with polymers to form an antimicrobial coating on the container surface. An invention disclosure and patent for the technology has been submitted to facilitate licensing by industry.

What this means: The surface coatings were activated by visible light to inactivate *E. coli* O157:H7 on the container surface, and in tests reduced the pathogen by 99.7 percent. The research further demonstrated that the developed methods and coating formula could be applied to different types of containers made of metal, wood, plastics, or paperboard, and for various foods, especially for fruits and vegetables.

Indicator 5: During 2016, 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.

The cost of interventions to improve the safety of food products is often unknown. ARS researchers in Wyndmoor, Pennsylvania, developed a formal cost model analysis for competitive exclusion microbes (CEM) for biocontrol of *Salmonella enterica* on tomatoes. The team found that the unit costs of CEM biocontrol range from 5 cents to 95 cents per kilogram of tomato for small-scale production and less than 1 cent per kilogram for large CEM production models. Since total variable costs for CEM were 95 percent of total production costs, the team determined that the use of CEM is best suited for large-scale application. However, the estimated total annual cost of CEM for control of *Salmonella enterica* on tomatoes is greater than sodium hypochlorite or gaseous chlorine dioxide.

What this means: While CEM is an effective treatment process, other chemical treatment methods are lower cost. For high-value produce, CEM may complement existing technologies if efficacy and delivery systems can be optimized and its effects on gut microflora and associated factors are further evaluated.

Indicator 6: During 2016, 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

Current meat inspection in slaughter plants for food safety and quality attributes, including potential fecal contamination, is conducted through visual examination by human inspectors. These inspectors work under conditions that are poorly suited to conventional fluorescence detection methods that require ambient darkness. ARS researchers in Beltsville, Maryland, developed a handheld fluorescence-based imaging device (HFID) to highlight contaminated food and equipment surfaces on a display monitor during use under ambient lighting. This study assessed the effectiveness of the HFID to enhance visual detection of fecal contamination on red meat, fat, and bone surfaces of beef under varying ambient luminous intensities. Overall, diluted feces were detectable on the beef surfaces under all but the brightest ambient light intensities tested in the fluorescence images. This technology is patented and under license and commercial development by an industry partner.

What this means: The results of this research will support and improve meat safety inspection programs implemented by U.S. processors and regulatory inspectors.

Improved analytical methods (more accurate, cheaper, and faster) are needed to better monitor pesticides and persistent organic pollutants in meat and poultry by food safety regulatory agencies such as the USDA Food Safety Inspection Service (FSIS). ARS researchers in Wyndmoor, Pennsylvania, developed and validated a new, easy, reliable, cost-effective, high-throughput analysis method for 192 diverse pesticides and 51 environmental contaminants found in cattle, swine, and poultry muscle. The new technology is based upon the previously ARS-developed QuEChERS approach now used worldwide.

What this means: The new method was successfully applied to the analysis of known contaminated meat samples that validated the utility of the method, which was transferred to the FSIS for implementation in routine regulatory monitoring of contaminants in meats.

Food adulteration is a critical and serious international issue. It is usually considered an act whereby food is contaminated with the intention to maximize economic profits. However, it consequently often results in reduced safety and quality which may lead to illnesses and deaths. For example, recent intentional contamination of milk-based infant formulae with melamine to mask the true protein level resulted in many illnesses and deaths, and an international recall of product. To provide regulatory agencies with the ability to detect adulterated products, for example, milk powder, ARS researchers in Beltsville, Maryland, developed a line-scan Raman chemical imaging system sensitive to 50 parts per million.

What this means: The new imaging system now under patent review can be used for rapid, nondestructive, continuous, and quantitative measurement of chemical adulterants present in dry powdered food ingredients.

Indicator 7: During 2016, 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.

The impact of potential antimicrobial resistant bacteria in livestock waste runoff has been a growing topic of public concern. ARS scientists in Clay Center, Nebraska, compared the populations of antimicrobial-resistant bacteria and the presence of antimicrobial resistance genes within samples of livestock and municipal waste streams discharged from municipal wastewater treatment facilities, cattle feedlot runoff catchment ponds, swine waste lagoons, and environments considered low impact (a municipal lake and a prairie). The results showed that the prevalence and concentrations of antimicrobial-resistant bacteria were similar among the livestock and municipal sample sources. But there were differences among the antimicrobial resistance genes found in agricultural, environmental, and municipal samples, with municipal samples harboring the highest number of antimicrobial resistance genes. It was concluded that antimicrobial resistance is a very widespread phenomenon where antimicrobial resistance can be found in cattle, swine, and human waste streams, though a higher diversity of antimicrobial resistance can be found in human waste streams.

What this means: This study indicates that antimicrobial resistance bacteria are widespread, and that humans are a reservoir of antimicrobial resistant bacteria for other humans. This was previously unknown and indicates that agricultural systems are not the only source of antimicrobial resistance.

Cattle are frequently administered macrolide antibiotics, such as Azithromycin and Erythromycin, for the prevention or treatment of various diseases. To examine the effect of macrolide exposure on fecal shedding of resistant bacteria, rapid methods for characterizing resistance gene content were needed. To address this need, ARS researchers in Clay Center, Nebraska, developed a method to detect seven major antibiotic resistance mechanisms simultaneously. This method was successfully used to screen more than 2,000 bacterial isolates, which revealed subpopulations of bacteria containing antibiotic resistance genes not previously recognized in these organisms.

What this means: This information will be useful for epidemiologists and scientists concerned with the lateral transfer of antibiotic resistance genes between pathogenic and commensal bacteria and the subsequent development of resistance.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 1.2

During FY 2017, 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. 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

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. 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

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 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.

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.

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 2016 PERFORMANCE REPORT FOR GOAL 1.3 - ACCOMPLISHMENTS

Indicator 1: During 2016, ARS will enable commercially-viable post-harvest technologies for non-food biobased products and for value-added non-food processing.

The yeast *Aureobasidium pullulans* is able to convert agricultural sugars to compounds called liamocins. These are selective antibacterial agents for controlling problematic bacteria in veterinary and clinical medicine. Liamocins are unique in that they have varying degrees of antimicrobial activity. ARS scientists in Peoria, Illinois, developed genetic methods to control the type of liamocin based on the sugar used to grow liamocin strains.

What this means: This technology allows production of specific liamocin strains that attack specific bacterial organisms, which benefits veterinary care by offering nonantibiotic treatment options.

Due to fierce global competition, the American leather and hide industries need to produce novel products from raw hides and recycled tannery waste to stay competitive. ARS researchers in Wyndmoor, Pennsylvania, recently developed novel collagen sponges from hides and tannery waste that have many unique properties desirable in medical applications. The sponges are widely used to stop bleeding in surgery and as “scaffold” material in tissue regeneration. Collagen sponges can be generated from untanned hides, limed hides, and delimed-bated hides, as well as tannery waste of limed splits and their trimmings. A cooperative agreement is being established with an industry partner to commercialize this technology.

What this means: This research is instrumental in helping the U.S. hides and leather industries diversify by producing bio-based sponges, which have many high-value medical applications.

Moisture content of cotton fiber is an important fiber property, but it is currently measured via a laborious, time-consuming, oven-drying method that has many performance issues. ARS scientists in New Orleans, Louisiana, developed a moisture meter using a microwave that performs rapid, precise, and accurate fiber moisture measurements. This microwave instrument, compared to two current oven-drying reference methods, had better precision of moisture measurements with near 99 percent accuracy. Also, the effect of the measurement method on the cotton fiber weight was minor, and long-term stability was excellent. An extensive, multi-month, on-site trial of the instrument was performed by the USDA Agricultural Marketing Service with favorable results. In addition, an international technology company is investigating potential food applications.

What this means: The microwave moisture method is viable and applicable for daily quality control use of cotton fiber.

Indicator 2: During 2016, 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.

Apple fruit superficial scald results from chilling stress during the first month after harvest and results in dark, sunken peel tissue after 3-6 months of cold storage. Low-oxygen controlled atmosphere storage can control superficial scald, but is not always effective on apples from different orchard lots and production seasons. ARS scientists in Wenatchee, Washington, have identified natural early warning compounds that accumulate in the peel of harvested apples before scald appears regardless of the prior growing conditions. When these early warning compounds occur, storage-room oxygen levels can be reduced or fruit can be marketed before symptoms develop.

What this means: This practice provides apple producers with methods to avoid superficial scald throughout the postharvest supply chain.

The U.S. Food and Drug Administration (FDA) and the Commission of European Communities require that gluten-free oats or products can be labeled as nongluten only if they contain less than 20 parts per million gluten, the established safe consumption limit for people with celiac disease. The need for testing samples for gluten products is highly sought by industry to assure that a gluten-free product can be delivered. In response to this need, a near-infrared instrument developed by ARS scientists in Manhattan, Kansas, was compared with a commercial near-infrared instrument to classify grain types on a single grain basis. Both instruments could distinguish oats and groat kernels from other grains with 95 to 100 percent accuracy. The in-house instrument had better accuracy, although it was a magnitude slower than the current commercial instrument.

What this means: This instrument, which is being tested by the FDA, provides an excellent method for evaluating commercial samples of gluten-containing products.

Replacing petroleum oils with plant oils in the production of usable by-products, such as plastics, is complicated. One problem with plant oils is that they contain more oxygen atoms than necessary to make by-products. These oxygen atoms must be removed to control reactions necessary for the plastic to be strong, durable, and useful. ARS scientists in Peoria, Illinois, developed a new technology that uses a very small amount of catalyst to remove excess oxygen with the only coproduct being carbon dioxide, which is captured. A patent application covering this technology has been filed.

What this means: The use of this technology would enable major industrial polymer partners to substitute petroleum oil for vegetable oil in making plastic products.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 1.3

During FY 2017, ARS will:

1. Enable commercially-viable post-harvest technologies for non-food biobased products and for value-added non-food processing.
2. 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.

During FY 2018, ARS will:

1. Enable commercially-viable post-harvest technologies for non-food biobased products and for value-added non-food processing.
2. 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.

During FY 2019, ARS will:

1. Enable commercially-viable post-harvest technologies for non-food biobased products and for value-added non-food processing.
2. 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.

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 2016 PERFORMANCE REPORT FOR GOAL 2.1 - ACCOMPLISHMENTS

Indicator 1: During 2016, ARS will develop new or improved guidelines, technologies, and/or knowledge to increase the effectiveness of agricultural water management.

Traditional U.S. rice production includes flooding rice fields for much of the growing season, but soil type and topography limit where flood management can be used. Following up on earlier research, ARS researchers in Portageville, Missouri, and collaborators demonstrated that center pivot irrigation schedules could be successfully adapted for rice production on coarse-textured soil characterized by high water infiltration rates.

What this means: Rice is a food staple in much of the world and these results will help rice producers optimize center pivot irrigation to reduce their water use on coarse soils.

Midwest U.S. climate change projections indicate that crop water deficits will increase and adversely impact production. Sub-irrigation, in which water is captured from crop fields and subsequently delivered to the plant root zone from below the soil surface, could help offset these water deficits. ARS researchers in Columbus, Ohio, and colleagues used historical sub-irrigated field crop yield data to determine an overall estimate of future northwest Ohio sub-irrigated field crop yield increases, based on climate projections for 2041 to 2070. They found that sub-irrigation increased overall field corn yields 20 percent in 1996-2008 for corn and 12 percent for soybean compared to fields with conventional unrestricted drainage. The benefit provided by sub-irrigation is projected to be substantially higher in the projected climate of 2041 – 2070, resulting in estimated yield increases of between 27 and 30 percent for corn and about 20 percent for soybean.

What this means: These findings suggest that as drought becomes more frequent, using agricultural water capture and sub-irrigation systems to boost crop yields could provide a viable climate adaptation strategy to help sustain agricultural production.

Crop water requirements can vary within a single field because there can be considerable variation in soil properties and plant characteristics. Variable rate irrigation (VRI) technology applies irrigation water at variable rates at specific sites within a single field. ARS scientists in Stoneville, Mississippi, conducted a 2-year field study in the Mississippi Delta to compare VRI management with conventional uniform rate irrigation (URI) management. They found that VRI yield was equivalent URI yield, but VRI management reduced irrigation water use by 25 percent. Irrigation water use efficiency for soybean and corn under VRI was 25 percent and 27 percent higher than in URI water use efficiency.

What this means: These findings indicate VRI management could be used to conserve irrigation water supplies in humid production regions.

Indicator 2: During 2016, ARS will develop new or improved guidelines, technologies, and/or knowledge to reduce erosion and sedimentation from agricultural lands and/or improve water quality.

Conventional tile risers improve agricultural productivity by draining excess water from low spots such as potholes but they also increase pesticide levels in runoff. ARS scientists in West Lafayette, Indiana, conducted a 6-year field study conclusively demonstrating that blind inlets (structures placed at the lowest point of a farmed depression) can reduce pesticide losses in runoff. Blind inlets reduced atrazine losses by 57 percent, alachlor losses by 58 percent, metolachlor losses by 53 percent, and glyphsate losses by 11 percent.

What this means: These findings demonstrate that blind inlets can enhance water conservation efforts by reducing pesticides and sediment in drainage runoff.

Siting conservation practices can be ineffective and costly because current watershed models do not adequately simulate processes associated with gullies, wetlands, and riparian buffers in the context of an agricultural watershed. ARS scientists in Oxford, Mississippi, collaborated to release the watershed planning tool AnnAGNPS v5.44, which contains enhanced gully, wetland and riparian buffer components for developing integrated conservation management practice watershed plans.

What this means: The AnnAGNPS watershed modeling tool helps evaluate the potential of conservation practices for reducing pollutants on a watershed scale, which helps watershed conservation managers determine the most cost-effective locations for conservation practices.

Nitrates lost from crop fields via drainage are a significant agricultural pollutant. In the Upper Mississippi River Basin, nitrate losses from agricultural fields are highest in spring when temperatures are low and flow rates are high. These factors slow the rate at which nitrate is biologically removed by woodchip-based bioreactors via microbial denitrification. ARS scientists in St. Paul, Minnesota, and Ames, Iowa, compared how effectively wood chips and crop residues (corn cobs, corn stover, and barley straw) removed nitrates in early spring (1.5°C) and summer (15°C). The nitrogen removal rates for agricultural residues, which contain higher bacterial populations, were higher than for woodchips. Residue removal rates were much lower at the colder temperature, suggesting that dissolved carbon availability limited denitrification.

What this means: Policy makers, engineers, and field technicians can use these results to design denitrifying bioreactor management that enhances nitrate removal.

Indicator 3: During 2016, 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.

Over the last two decades, beetle infestations have killed billions of trees and affected millions of acres of forest in the Rocky Mountains. Many of these forests are at the headwaters of rivers vital to western U.S. water supplies. ARS scientists in Tucson, Arizona, collaborated with others to measure and compare annual streamflow following tree mortality with 25 to 40 years of pre-mortality streamflow. Scientists observed only small overall changes, including both increased and decreased streamflow. They found die-off reduces the amount of precipitation intercepted by forest canopy and taken up by plant roots, which increases precipitation contributions to streamflow; and it also increases snow sublimation and evaporation, which reduces precipitation contributions to streamflow. These results are consistent with recent studies of forest hydrologic processes and indicate that streamflow from forested headwaters is resilient to tree die-off.

What this means: Ongoing research to predict the net effect of these trade-offs will improve water supply prediction and inform adaptive management of forested watersheds.

Assessing how watershed dynamics are affected by a range of environmental and anthropogenic variables requires the ability to integrate and model biophysical responses, environmental problems, policies, economic activity, and subsurface and surface watershed datasets. A team of ARS scientists in El Reno, Oklahoma; Bushland, Texas; Temple, Texas; and Texas A&M University in College Station, Texas, linked the Soil and Water Assessment Tool and Modular Three-Dimensional Finite-Difference Groundwater Flow models to improve hydrologic and water quality simulations in the surface and groundwater domains. They developed a new application tool called SWATmf and found it generated simulated streamflow and groundwater levels that generally agreed with observations. These results indicate SWATmf can be used for simulating surface and groundwater interactions.

What this means: The integrated modeling framework is expected to improve watershed-scale model simulations and provide a modeling platform that resource managers can use to better understand linked surface-subsurface hydrologic processes and associated transport phenomena under time-variant conditions.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 2.1

During FY 2017, 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 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, 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 – CLIMATE CHANGE, SOILS, AND EMISSIONS RESEARCH

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 2016, ARS will assess the potential risks and benefits to agricultural systems from climate change, and develop agricultural management practices and decision support strategies that enable producers to take advantage of the beneficial effects, and adapt to the adverse effects of climate change.

In the Mediterranean-type climate of the Pacific Northwest, thick layers of crop residues are often left on fields at harvest, but they are not effective in preventing significant amounts of evaporation over the summer fallow period. Historically, these residues are often removed or tilled into the soil. Using weighing lysimeters, field plots, and samples from farmers' fields, ARS researchers at Pendleton, Oregon, learned that residue cover approaching 100 percent is very effective at improving deep penetration and storage of early fall rains. Residue cover of less than 50 percent, however, was much less effective, and moisture from small rain events would often evaporate completely. Since small rain events are very important to wheat yields in semi-arid areas, this information has encouraged farmers to develop ways to maintain residue cover, to plant through higher levels of residue cover, and to abandon management practices that remove residue from the field.

What this means: These practices will lead to yield increases, help protect soil quality, and provide improved climate resilience.

Warmer and drier climates predicted for the coming decades could impact agriculture and wind erosion in the Pacific Northwest. PM10, microscopic particulate matter less than or equal to 10 microns in diameter, is often a respiratory risk and is of particular concern in the Pacific Northwest. This is because PM10 emissions from agricultural lands can cause elevated atmospheric concentrations of the particulates that at times exceed National Ambient Air Quality Standards. ARS scientists in Pullman, Washington, and University of Idaho collaborators simulated climate change impacts on wind erosion and emissions using state-of-art climate forecasts and wind erosion technologies. They found that, even with the projection of a warmer climate, wind erosion and PM10 emissions in the Pacific Northwest are predicted to decrease by 2050, largely as a result of enhanced biomass production that will protect the soil from erosion.

What this means: The results of this research will inform State air quality and agriculture agencies and may be used in shaping future state standards or regulations.

Indicator 2: During 2016, ARS will develop management practices and decision tools to improve soil quality, protect the environment, and contribute to the sustainability of agricultural systems.

There have been limited studies of soil carbon sequestration rates and other changes in soil chemical properties under long-term conservation and conventional tillage. ARS scientists in Florence, South Carolina, created a 34-year tillage and crop management experiment on sandy soils. They found that it took a few decades to accumulate a significant amount of topsoil organic carbon, but that over the 34-year study, conservation tillage resulted in a net accumulation of about seven metric tons per hectare of soil organic carbon, compared to conventional tillage. During the 34-year course of this experiment, 25 metric tons of carbon dioxide equivalents per hectare were sequestered.

What this means: These results affirm that conservation tillage management can benefit U.S. producers by increasing soil organic carbon content and reducing greenhouse gas emissions from agricultural production.

Earthworms are responsible for a number of important processes in soil modification and restructuring. They decompose surface litter, move organic matter from the surface down into the soil, digest and decompose soil organic matter, and create tunnels that alter soil porosity. Earthworms are often divided into functional groups based on their feeding and burrowing behaviors, and it is assumed that all species within each functional group will have similar effects on soil organic matter. ARS researchers in Beltsville, Maryland, found that certain earthworm species within these functional groups affected these processes differently. For example, some species within each functional group had different impacts on soil microbiological activity, the incorporation of surface litter into soil organic matter, and changes in the abundance of soil bacteria and fungi. These effects varied according to the specific earthworm species, highlighting the need to incorporate species information into studies on earthworms and soil organic matter.

What this means: These results will be useful to soil ecologists and may lead to strategies for managing earthworms and other soil biota in improving the sustainability of agroecosystems.

Indicator 3: During 2016, ARS will assess the greenhouse gas emissions from agricultural systems and develop methods for reducing the emissions.

While U.S. agriculture has historically been a significant source of greenhouse gas (GHG) emissions, agricultural soil management practices have been developed and are under continued development that curtail these emissions. As a result, it has been demonstrated that many U.S. agricultural soils now sequester significant levels of the GHG carbon that might otherwise have been emitted into the atmosphere. The primary objective of GRACEnet is to identify, develop, and improve agricultural practices that will enhance carbon sequestration in soils, promote sustainability, and provide a sound scientific basis for carbon credits and related environmental markets. Major GRACEnet products include establishing field/laboratory measurement protocols; creating a standardized Excel data entry template; developing software for data entry quality control; creating a Web-accessible GRACEnet/Resilient Economic Agricultural Practices (REAP) database with field measurements, site characterization data, and land management information; and the publication of more than 800 journal articles/book chapters with project results.

What this means: GRACEnet data have increased the accuracy of soil GHG emission estimates reported in the U.S. national GHG inventory and have been used to develop factors imbedded in decision support tools to quantify the GHG benefits of improved management practices. In addition, GRACEnet data have been used to validate the underlying models used by the Natural Resources Conservation Service COMET-Farm decision support tool, a program agricultural producers can use to calculate how much carbon their conservation actions can remove from the atmosphere.

ARS researchers in Fort Collins, Colorado, and Colorado State University collaborators studied the effects of cattle excrement patches on nitrous oxide and methane fluxes in both cool-season pastures and warm-season native rangelands in a northern Colorado shortgrass steppe ecosystem. Measured nitrous oxide emissions from manure nitrogen were substantially lower than the default emission values established by the Intergovernmental Panel on Climate Change (IPCC) for manured pasture. These findings suggest that IPCC default values significantly overestimate nitrous oxide and methane emissions from both the shortgrass steppe native rangeland and cool-season pasture during drought.

What this means: This indicates the need to improve IPCC simulations to increase the accuracy of their estimates of agricultural contributions to greenhouse gases.

Hydrogen sulfide gas from swine manure slurries represents a health risk and odor nuisance. Increasing the use of dried distillers' grains with solubles (DDGS) in swine diets has contributed to increasing levels of hydrogen sulfide emissions. ARS scientists in Ames, Iowa, conducted an animal feeding trial that investigated how sulfur levels and sulfur sources in swine diets affect hydrogen sulfide emissions. They found that increasing sulfur levels in swine diets significantly increases hydrogen sulfide emissions and odor and that diets enriched with sulfur amino acids also increase sulfur odor emissions. Another study demonstrated that the composition of animal feed can increase hydrogen sulfide and odor emissions.

What this means: Information from these studies will help growers, engineers, and regulatory officials develop guidelines for alternative diets with reduced sulfur levels, which will help reduce noxious hydrogen sulfide emissions.

FY 2017-2019 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 2017, 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 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.

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 2016 PERFORMANCE REPORT FOR GOAL 2.3 - ACCOMPLISHMENTS

Indicator 1: During 2016, 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.

Developing cost-effective cellulosic ethanol production is difficult in part because of the expensive cellulolytic enzymes needed to break down biofeedstock before it can be converted into fuel. Researchers are also studying ways to manage inhibitory compounds that can result from fermentation and slow the conversion of biofeedstock to cellulosic ethanol. ARS scientists in Peoria, Illinois, worked with partners to develop a new yeast strain with a unique cellulolytic enzyme that efficiently breaks down biofeedstock, shows resistance to inhibitory compounds, and eliminates the need to add other enzymes to the production process. The scientists assessed the efficiency of this yeast strain in converting pretreated rice straw into cellulosic ethanol and obtained a production rate of 36.7 grams per liter in 36 hours with a conversion efficiency of 90.1 percent. This translates into reducing enzyme costs in cellulosic ethanol production by around 35 cents per gallon.

What this means: This technology supports the rural economy and is expected to reduce risks and increase profitability in existing industrial biorefineries that produce ethanol and other products.

ARS researchers in Peoria, Illinois, worked with partners to demonstrate the feasibility of directly converting extracted plant sugars into oils that could be used as biodiesel or bio-jet fuel. This new process is suitable for producing a renewable intermediate for biodiesel or bio-jet fuel production. It is cost competitive with petroleum-based oils because sugars are extracted from plants without using enzymes that typically drive up costs in producing sugars from plant fibers.

What this means: Preliminary findings suggest this technology could reduce cellulosic ethanol production costs by 16 to 20 percent.

Maximizing cellulosic ethanol production rates requires the complete and efficient utilization of all biofeedstock sugars. Although some robust yeasts effectively covert plant sugars in industrial biorefining conditions, their conversion rates can be reduced by inhibitors formed during the production process. After a yeast strain from a Brazilian fuel ethanol production facility was found to tolerate these inhibitors, ARS scientists in Peoria, Illinois, engineered the yeast to convert plant xylose to ethanol and then identified a strain with excellent performance. They found that when this yeast strain was used to convert hydrolyzed switchgrass into cellulosic ethanol, it produced 30 percent more ethanol than the original parent strain.

What this means: Using this new strain is expected to reduce production costs for any cellulosic production process that uses biomass-derived sugars, which will help increase profits.

Indicator 2: During 2016, ARS will enable technologies for the production of new biofuels which are compatible with the Nation's existing fuel distribution infrastructure.

The cost-effective production of fuels and chemicals from agricultural residues requires a microorganism that can convert all the available sugars in the biofeedstock. ARS scientists in Peoria, Illinois, identified a strain of yeast that can convert inulin, a major polysaccharide derived from coffee processing waste, into cellulosic ethanol.

What this means: Using this yeast provides a new method for disposing of waste products from coffee processing and furthers the development of environmentally cost-effective and potentially profitable processes for managing agricultural byproducts.

Gas chromatography has traditionally been used to analyze wax components, but the high temperatures used in the process can lead to inaccurate results. ARS researchers in Wyndmoor, Pennsylvania, developed a new high performance liquid chromatography (HPLC) method to quantitatively analyze sorghum wax. This is the first successful HPLC method for waxes and employs evaporative light scattering detection to accurately quantify sorghum wax in sorghum oil, distillers milo oil, and in sorghum grain processing fractions such as bran and distillers dried grains. It also is very useful in analyzing commercial waxes, such as carnauba wax, candelilla wax, sunflower wax, rice bran wax, and beeswax.

What this means: This new HPLC method has the potential to become widely used for commercial wax analysis.

Producers, breeders, and manufacturers need quick and cost-effective methods to measure quality traits in new sweet sorghum feedstocks used for manufacturing biofuels and bioproducts. ARS scientists at New Orleans, Louisiana, developed a multivariate statistical methodology that uses inexpensive fluorescence and light absorption/reflectance observations to predict key sweet sorghum genotype traits. This new technique allows breeders and growers to predict sugar concentrations or selected impurities in juice or bagasse samples. Current advanced statistical pattern recognition methods were also used with sorghum grain samples to understand the chemical traits responsible for the pest (aphid/worm/bird) resistance.

What this means: This new technique replaces near-infrared and chromatography techniques and will help breeders and others advance the cost-effective production of cellulosic ethanol using sweet sorghum biofeedstocks.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 2.3

During FY 2017, ARS will:

1. Enable technologies that can reduce business risks, increase the value of co-products, and/or expand the number of revenue streams for existing biorefineries.
2. Enable technologies for the production of new biofuels which are compatible with the Nation's existing fuel distribution infrastructure.

During FY 2018, ARS will:

1. Enable technologies that can reduce business risks, increase the value of co-products, and/or expand the number of revenue streams for existing biorefineries.
2. Enable technologies for the production of new biofuels which are compatible with the Nation's existing fuel distribution infrastructure.

During FY 2019, ARS will:

1. Enable commercially-viable post-harvest technologies for non-food biobased products and for value-added non-food processing.
2. 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.

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 feed stock 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 2016 PERFORMANCE REPORT FOR GOAL 2.4 - ACCOMPLISHMENTS

Indicator 1: During 2016, ARS will increase utilization of manure nutrients and resources.

The agriculture community in the Southeastern Coastal Plain needs strategies for addressing regional soil issues, such as low water holding capacity and low fertility. These soil conditions reduce nutrient retention and soil health, which lead to reduced crop yields. Some biochar soil amendments have been shown to positively affect soil microbes, with a resulting impact of improved soil health and fertility. ARS researchers in Florence, South Carolina, collaborated with the U.S. Environmental Protection Agency to assess how manure-based biochar amendments affected the composition of microbial communities in two typical Coastal Plains soils. They found amendments supported significant shifts in microbial community composition and that these changes were greater in Norfolk soils than in Coxville soils. Additionally, these microbial community shifts correlated with availability of nutrients such as phosphorus, which increased as a result of the biochar amendment.

What this means: These results indicate manure-based biochars can improve soil biological properties that support healthier and more fertile soils, which will improve producer profits and agroecosystem sustainability.

Poultry litter is a solid material that is a mixture of chicken manure and bedding material. This litter is commonly used as a fertilizer on pastures and cropland and is typically applied by broadcasting the litter on the soil surface. Rainfall runoff from fields where poultry litter has been applied may carry phosphorus and nitrogen nutrients from the soil into streams, lakes, and other water bodies. This nutrient-rich runoff contributes to eutrophication and the growth of toxic algae in surface waters. Liquid manure from dairy cows, hogs, and laying hens is often applied by injecting it beneath the soil surface, a technique that helps control odor and reduce nutrient losses. An implement for subsurface application of solid manure, such as poultry litter, has not been available, so a prototype implement for applying poultry litter in shallow trenches and covering the litter with soil was developed by ARS scientists in Auburn, Alabama. The implement is equipped with four trenching devices and applies litter in four subsurface bands simultaneously. The implement works well for side-dressing litter to row crops and for subsurface band application of litter in pastures.

What this means: This new technology could provide producers with a more environmentally sustainable process for fertilizing their fields with poultry litter.

Indicator 2: During 2016, ARS will reduce manure pathogens and Pharmaceutically Active Compounds (PACs).

Airborne pathogens generated during manure management are a potential health risk, but these pathogens are often not recovered from liquid-based bioaerosol samplers. ARS researchers in Kimberly, Idaho, evaluated the effectiveness of several low-viscosity collection fluids to improve the recovery of viable *E. coli* cells from samplers that monitor pathogen levels. Viable *E. coli* recovery rates ranged from 87 to 98 percent after 90 minutes of operating samplers with peptone or antifoam agents in comparison to lower recoveries using simple buffers or water. The results indicate that using these substances or similar agents will help organisms survive stresses associated with the sampling process and improve the accuracy of bioaerosol sampling.

What this means: More accurate sampling will help researchers better assess the abundance of airborne pathogens that may present a quantifiable risk to human health.

Technology that enables fast and reliable detection and measurement of *E. coli* O157:H7 in food and environmental samples is a critical need for food safety and public health assessments. An ARS scientist from Riverside, California, and California State Polytechnic University partners used recombinase polymerase amplification (RPA) for the rapid detection of *E. coli* O157 and droplet digital polymerase chain reaction (ddPCR) for accurate *E. coli* O157:H7 measurement. The assays were applied to swine, dairy, beef, duck manure, and waste water effluent collected from a dairy wetland over a 12-month period. Quantification by ddPCR was able to distinguish *E. coli* O157:H7 from environmental samples with 75 percent sensitivity and 80 percent specificity.

What this means: These new methods improve the process of identifying factors linked to the contamination of surface and ground waters used for fresh produce irrigation, which will help producers identify irrigation water that may be contaminated with *E. coli* O157 pathogens, protect fresh produce from pathogens that cause serious foodborne illness, and protect consumers from foodborne illness.

Indicator 3: During 2016, ARS will reduce atmospheric emissions from animal production facilities.

People who live near swine production facilities are often affected by noxious odors from the facilities. One of the problems with designing animal trials to assess odor-reduction strategies is that they are often hampered by uncertainty about optimal scheduling for measuring odor compounds. ARS researchers in Ames, Iowa, investigated the length of time needed to conduct a valid feeding trial for evaluating odor emissions. They found chemical compounds making up odors did not stabilize until 5 weeks into the animal trial; thus experiments to determine the effectiveness of odor-reduction strategies should be performed for at least that long. Previous odor-reduction experiments reported in the scientific literature were performed for as little as 1 week.

What this means: This result provides valuable information for the design of future experiments on odor reduction, including the need for extended trials, which will require additional time and funding.

Dairy cows contribute to greenhouse gas emissions and global climate change directly via enteric methane emissions and indirectly via nitrous oxide and ammonia emissions from their manure. ARS researchers in Madison, Wisconsin, conducted a pilot project to see if they could reduce cow gas emissions over extended periods (periods lasting over a month) by adding condensed tannins extracted from Quebracho trees to dairy cow diets. Tannins are compounds naturally present in tree leaves, and Quebracho trees are found in South America. While the pilot project results were not statistically significant because of the small sample size and wide responses, the scientists found that overall, adding these tannins to livestock diets lowered methane emissions by 33 percent, nitrous oxide emissions by 70 percent, and ammonia emissions by 23 percent, and did not affect milk production.

What this means: While these results warrant further study, they suggest that dairy producers may be able to use relatively low amounts of tannins to reduce cow gas emissions throughout lactation, which could provide a potential long-term strategy to significantly improve the environmental sustainability of milk production.

Indicator 4: During 2016, ARS will develop beneficial uses of agricultural, industrial, and municipal byproducts.

Textile, leather, rubber, plastics, and food industries use synthetic dyes such as methylene blue to color their products. The wastewater generated by these processes commonly contains toxic compounds and/or carcinogens, is highly colored, and is commonly discharged into the environment. This contaminated discharge lowers oxygen levels and reduces light levels in the receiving waters, which leads to reduced photosynthesis in aquatic environments. ARS scientists from Bowling Green, Kentucky, used an acid dissolution-precipitation process to extract silica and residual ash from agro-industrial residues and found the silica and ash provided a low-cost adsorbent for removing methylene blue from aqueous waste streams.

What this means: These findings can potentially lead to an eco-friendly and sustainable method for transforming agro-industrial wastes into value-added starting materials for different industrial applications, as well as for developing adsorbent materials that can be used to treat chemical pollution.

There are growing concerns regarding the fate of nutrients, especially phosphorus, from land application of animal waste. One approach to reduce runoff losses of phosphorus is to treat manure or the soil receiving manure with chemical amendments such as gypsum. ARS scientists conducted a simulation study to see if flue gas desulfurization (FGD) gypsum applications reduced phosphorus loads in Coastal Plains soil runoff. They found that applying a specific amount of gypsum reduced soluble reactive phosphorus load by 51 percent and that measurements of heavy metals in runoff were all found to be either below detection limits or similar to levels found with no gypsum application. The results indicate that use of FGD gypsum on pastures receiving poultry litter in the Coastal Plains would be an effective method of reducing reactive phosphorus losses to the environment and controlling agricultural pollutants.

What this means: Based on this work, USDA's National Resources Conservation Service has adopted the use of gypsum with manure application as an NRCS National Standard.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 2.4

Note: The research for Goal 2.4 will be combined into Goal 2.2 starting with Fiscal Year 2017.

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 agro ecosystems 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 2016 PERFORMANCE REPORT FOR GOAL 2.5 - ACCOMPLISHMENTS

Indicator 1: During 2016, ARS will provide improved germplasm and cultivars that can be released for pasture, harvested forages, turf, biofuels, rangeland restoration, and conservation.

Endophytes are microorganisms that live symbiotically within plants and may improve plant tolerance to abiotic and biotic stresses. ARS researchers in Corvallis, Oregon, isolated and identified 111 fungal endophytes in 39 genera and 133 different bacterial endophytes in 37 different genera/species, of which 94 were unique isolates. The endophytes were collected from eight different grass species growing in saline environments and sandy soils along the Oregon coast. Fourteen of the bacterial isolates possessed an enzyme associated with improved plant growth under stress.

What this means: These newly discovered endophytes have the potential to improve the health and productivity of grasses and other crop species grown in marginal or stressful conditions.

Many areas of the western United States have been severely degraded by human disturbance, wildfires, and the invasion of weedy annual plant species, such as cheatgrass and medusahead rye. ARS scientists in Logan, Utah, developed and released Trailhead II, a wildrye cultivar that stands 3 to 6 feet tall and is ideal for providing wind protection in winter calving pastures. Mature plants are also nutritious (8 percent protein), and withstand heavy grazing and trampling in its dormant state. Because it is a drought-tolerant bunch type grass with a fibrous root system and adequate seedling vigor in arid regions, it is well adapted for stabilizing disturbed soils.

What this means: Trailhead II's characteristics, plus its rapid emergence and overall potential for rapid establishment, make it a desirable plant material for reclamation, conservation, and re-vegetation plantings in the Intermountain West and Northern Great Plains areas of the United States.

Indicator 2: During 2016, ARS will provide forage, pasture, and rangeland management technologies and strategies that reduce inputs while improving livestock performance and sustaining the environment.

ARS scientists in Reno, Nevada, collaborated with a range consultant and completed research on the effect of both traditional and holistic grazing management systems on soil properties in New Mexico. Traditional grazing, as practiced in this region, is typically year-round with a stocking rate of one cow per 56 acres. The holistic system requires the land be separated into more pastures, because cattle graze each pasture for only 3 to 5 days and then are rotated to another pasture while the grazed pasture is rested for 100 days. Under the holistic management system, stocking rate was increased to one cow per 35 acres. The scientists found that even with the increased stocking rate, rangelands managed using holistic principles had significantly greater total soil nitrogen and total soil carbon than traditionally grazed rangelands, with less proportion of bare ground and increased forage production.

What this means: These results indicate that a more holistic approach to grazing management can improve rangeland ecosystem health and environmental sustainability.

North-central U.S. dairy producers often rely on stored forages to maintain livestock through the winter. Fall-grown oat is an excellent forage candidate because it is a late-season crop with good yield potential, facilitates the application of manure soil amendments during the summer, and helps reduce nitrogen losses to the environment. ARS researchers in Marshfield, Wisconsin, found that using nitrogen fertilizers increased fall seeded oat yields by 50 percent or more, that dairy manure applied in summer provided adequate nitrogen, and that oats aggressively take up soil nitrogen. They also determined that heifers managed in central Wisconsin should begin grazing fall seeded oats in late September because waiting until mid-October resulted in reduced heifer growth, particularly if rapidly maturing oat types were used.

What this means: This improved fall oat management information provides dairy producers with information they can use to produce quality animal feed (stored or grazed) and reduce the environmental risk of nitrogen leaching to groundwater.

Exotic annual grasses, such as cheatgrass, now grow on nearly 100 million acres of western U.S. rangeland. Dry cheatgrass stands increase the amount of highly flammable fine fuels in infested areas, which in turn increases the frequency, size, and heat intensity of wildfires. These wildfires threaten human safety, reduce livestock forage, and degrade wildlife habitat. They also create conditions that support cheatgrass expansion, which crowds out natives plants in rangeland ecosystems. Cheatgrass mitigation efforts have focused on reseeding or replanting native plants after a wildfire, but these efforts have had only limited success. ARS scientists in Burns, Oregon, have developed management strategies to effectively reduce fine fuel loads. They developed a model and research framework for using pre-fire fuel-load management (including livestock grazing) to reduce the loss of desired native plants during wildfires and reduce reliance on post-fire seeding practices that are often ineffective. These strategies provide ways to preserve native plant ecosystems and reduce losses when fires do occur, and reduce the likelihood of cheatgrass invasion.

What this means: This work provides ranchers and public land managers with strategies for preemptive fuels management, and serves as a framework for identifying key research questions to guide future studies.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 2.5

During FY 2017, 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 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.

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 (GAO) 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 2016 PERFORMANCE REPORT FOR GOAL 2.6 - ACCOMPLISHMENTS

Indicator 1: During 2016, ARS will develop integrated solutions to solve challenges related to agricultural system productivity, profitability, energy efficiency, and natural resource stewardship.

Conventional harvest practices often include bulking high-protein wheat, which typically has a higher commodity value, together with other harvested wheat grains. ARS scientists in Pendleton, Oregon, designed and constructed a complete harvesting system consisting of 1) an optical sensor for measuring grain protein on a combine harvester, 2) an electrical/mechanical device for physically separating low- and high-quality grain during harvest, and 3) software for calculating the best economic point at which to segregate grain into two bins. They tested this system to determine if segregating hard red spring wheat into two bins was more profitable than conventional bulking into one bin. Their results indicated that segregating wheat by protein content can, under certain conditions, increase the value of each bushel of grain; during years with large market price spreads and above average yields, net returns from segregating wheat were up to $9.32 per acre greater than returns from bulking into a single bin.

What this means: Growers can use this system to evaluate potential returns from grain segregation when economic conditions favor grain segregation, which will potentially improve producer profits.

Growth models that simulate corn growth predict plant water-use rates to estimate how many days growth can occur following a rain or irrigation event before the soil water supply is exhausted. Eight years of water use (evapotranspiration or ET) measurements collected by an ARS researcher in Ames, Iowa, were used for comparison testing as part of the international Agricultural Model Inter-comparison and Improvement Project (AgMIP). An ARS collaborator in Maricopa, Arizona, compiled initial ET predictions from 24 models run by 16 research groups around the world, including ARS researchers in Maricopa and Beltsville, Maryland. ET estimates from the models were found to vary by almost a factor of four and many of the predictions differed greatly from measured water use.

What this means: This test conclusively identifies a weakness of many crop growth models and highlights the need for focused research to improve model routines for calculating crop water use. More realistic simulation model results will lead to better management and policy decisions by stakeholders, ranging from producers to strategic decision makers.

Projected increases of air temperatures have the potential to affect plant growth, but different crop varieties may be affected in different ways because of genetic variability. ARS researchers in Ames, Iowa, evaluated how high temperatures affected growth rates and grain yields of three corn hybrids. All three hybrids showed a faster rate of growth and large grain yield reductions when grown under higher air temperatures that are expected to occur by the end of this century. The most significant air temperature factor affecting grain yield was exposure to high nighttime temperatures during the grain-filling period.

What this means: These results will help the development of new varieties and management practices for crop production as environmental growing conditions change.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 2.6

During FY 2017, ARS will:

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

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.

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 2016 PERFORMANCE REPORT FOR GOAL 3.1 - ACCOMPLISHMENTS

Indicator 1: During 2016, ARS will breed superior new crops, varieties, and enhanced germplasm.

Drought is a major problem for many crops, but has not been thoroughly addressed in soybean research. Drought-resistant soybean cultivars are virtually non-existent in the United States, and the first drought-resistant Asian soybean accession from the USDA National Plant Germplasm System (NPGS) was reported only in 1989. ARS researchers in Raleigh, North Carolina, using classical breeding methods, have incorporated drought resistance traits from the Asian accession into a new high-yielding cultivar 'USDA-N8002'. The newly released cultivar exhibits slow, or delayed canopy-wilting, sustained nitrogen fixation during drought stress, and a water-conserving transpiration response when exposed to atmospheric vapor pressure deficit conditions. It has very stable yields over the southeast United States in both full season and double-cropping production.

What this means: This new cultivar is available for production and for use as parental stock for commercial breeding programs aimed at breeding drought resistance into soybean cultivars.

Health professionals and consumers are placing increased importance on the nutritional value of foods, a key component of food security. Consumers are also increasingly demanding that their food be produced using less agrochemicals, which is problematic for potato producers since they commonly have to apply fungicides throughout the growing season to control diseases. Potatoes are nutritionally dense crops that are very low in fat, while being rich sources of protein, fiber, antioxidants, minerals, and calories. ARS scientists in Prosser, Washington, working with collaborators in the TriState Breeding Program, released two new high-phytonutrient potato varieties. "Yukon Nugget" and "Smilin' Eyes" are yellow flesh potato varieties that have higher yields, improved disease resistance, and greater anti-oxidant concentrations than "Yukon Gold," the standard commercial yellow flesh potato variety.

What this means: These new varieties enable growers to produce potatoes that require fewer applications of chemicals to control disease and meet evolving consumer preferences for nutritional foods.

Indicator 2: During 2016, ARS will devise innovative approaches to crop genetic improvement and trait analysis.

The data generated by U.S. maize and rice geneticists is expanding rapidly, as is the demand for bioinformatic tools that enable researchers and breeders to utilize this knowledge. ARS scientists in Ames, Iowa, and Stuttgart, Arkansas, developed three new bioinformatic tools to accelerate maize (corn) and rice breeding and research. First, the MaizeGDB Genotype Visualization Tool enables maize researchers to survey the genomes of 17,000 maize lines and display all DNA differences in any region of their respective genomes. The MaizeGDB Pedigree Viewer enables breeders to visualize pedigree relationships between maize germplasm lines and identify the best lines genetically as parents for crossing. Combined with knowledge of maize genome functional variation in MaizeGDB, these tools enable breeders to select maize lines to cross for making improvements to germplasm. For rice breeders, ARS scientists in Stuttgart, Arkansas, created Ricebase, a new database integrating rice genetic variation, pedigrees, and whole-genome-based data, thus accelerating the discovery and design of molecular markers for marker-assisted breeding and selection and enabling rice breeders to accelerate their selections more efficiently.

What this means: These powerful, new, bioinformatic tools enable maize and rice researchers to leverage USDA's open germplasm, data, and information for crop improvement.

Wheat flour is one of eight foods responsible for 90 percent of food allergies in the United States. ARS scientists in Albany, California, created transgenic wheat lines in which the omega-5 gliadins, the major sensitizing allergens in a severe food allergy called wheat-dependent exercise-induced anaphylaxis (WDEIA), were significantly reduced in the flour without adverse effects on flour quality. In collaboration with scientists at the French National Institute for Agricultural Research (INRA), the allergenic potential of these lines was evaluated using sera from a collection of WDEIA patients. Most patients showed little or no reactivity to omega-5 gliadins in the transgenic lines, indicating that the transgenic lines could be considered reduced-allergen. However, low levels of reactivity with other gluten proteins were also observed with the transgenic lines.

What this means: While flour from the transgenic lines would not be suitable for individuals diagnosed with WDEIA, introduction of wheat lacking omega-5 gliadins could reduce the number of consumers who become sensitized to these proteins and decrease the overall incidence of this food allergy.

Indicator 3: During 2016, ARS will expand crop genomic information resources and advanced bioinformatic capabilities.

Carrots are nutritionally dense vegetables that are rich sources of fiber, antioxidants, and minerals. However, carrot producers in the United States suffer millions of dollars of losses annually due to pathogenic nematodes. The development of improved carrot varieties has been impeded by a lack of understanding of the carrot genome. ARS scientists in Madison, Wisconsin, led an effort involving 20 scientists from seven countries that sequenced the carrot genome. The researchers identified genes involved in nematode resistance, resistance to environmental stresses, and the production and accumulation of phytonutrients.

What this means: This research significantly advanced our understanding of the genetic control of orange and yellow pigment development and the genetic control of important traits that breeders will be able to use to accelerate the development of carrot varieties with enhanced disease resistance and improved nutritional qualities. This information will also be used to identify gaps in the U.S. national carrot germplasm collection that require filling.

A crop reference genome sequence is the foundation for accelerating modern crop breeding and genetic studies. ARS scientists in Stoneville, Mississippi; Ames, Iowa; and Tifton, Georgia, along with their partners, sequenced the genomes of two wild relatives of cultivated peanut whose ancestors merged to form a new species. This new species was then domesticated to become the modern cultivated peanut. An important finding of this research is that the unusual hybridization of these two species was likely the direct result of early agriculturalists in South America. The genome sequences from these wild species comprise essentially all of the genetic material in the modern cultivated peanut.

What this means: This research will provide the foundation for plant researchers and breeders to more efficiently select for improved peanut varieties and to speed development of varieties better suited for growing in various regions of the world. The genome sequence has already been used to help identify mechanisms for resistance to root-knot nematodes and rust (a fungal disease), serious challenges for many peanut farmers.

Indicator 4: During 2016, ARS will conserve and encourage the use of plant and microbial genetic resources and associated information.

Each year, more than 13 million boxwood plants are sold in the United States, making boxwood one of the most popular shrubs in the American landscape. A new blight disease, caused by the fungus *Calonectria pseudonaviculata*, is causing devastating losses to boxwood throughout the northeast and mid-Atlantic United States. Developing disease-resistant cultivars of boxwood is the only long-term sustainable solution to this problem, but it has been difficult to rapidly identify plants with this trait. ARS scientists at the U.S. National Arboretum in Washington, D.C., developed a method using detached leaves to quickly and effectively screen boxwood for blight resistance.

What this means: The screening method is being used by plant breeders to quickly identify plants with disease resistance. Resistant plants can then be used as parents to develop new boxwood varieties with improved blight resistance, which reduces losses to nurseries and the landscape of the eastern United States.

Sunflower crop wild relatives include interspecific relatives, containing a large gene pool of 53 different species that possess useful genes needed for maintaining genetic diversity. It is extremely challenging to mine these genes, especially due to incompatibility issues, such as hybridization barriers between cultivated sunflower and the perennial species. Successful hybridization by ARS scientists in Fargo, North Dakota, produced “amphidiploids” containing a full balanced set of chromosomes from both the crop wild relative and the cultivated sunflower, overcoming common fertility problems often encountered when making wide crosses. The team developed six genetic stocks derived from different wild sunflower species. The value of these interspecific amphiploid genetic stocks is that they can act as a bridge in interspecific gene transfer, allowing for easier backcrossing with the cultivated sunflower to further broaden the genetic diversity of the sunflower crop, as well as to transfer useful target genes for specific traits. The genetic stocks will also allow development of chromosome addition lines containing chromosomes of individual wild species that will be useful in studying the genetics of wild species.

What this means: These amphiploids give sunflower breeders increased access to more genetic diversity that has been extremely difficult to obtain using traditional breeding methods.

Indicator 5: During 2016, ARS will expand fundamental knowledge of plant biological and molecular processes.

Drought is one of the major environmental stresses constraining agricultural production. Plants have evolved diverse strategies to respond to drought, including increasing production of the hormone abscisic acid (ABA). An ARS researcher in Davis, California, in collaboration with researchers at the University of California, Davis, have produced transgenic petunias that increase ABA concentrations when exposed to drought stress. The plants were not only resistant to severe drought, but fully recovered when water stress was lifted. Additionally, these plants grew like traditional petunias in the absence of drought stress.

What this means: These results demonstrate an example of the successful modification of plants to improve drought tolerance, an approach that could be useful when applied to improve drought resistance in other crops.

Grafting has been widely practiced for centuries for the propagation and production of many vegetable and fruit crops, including grapes. However, the underlying mechanism of how two grafted partners communicate to produce a successful graft are largely unknown. ARS researchers in Geneva, New York, identified 3,000 genes whose genetic code is transported across graft junctions via messenger RNAs (mRNA) in the field. While many biological processes and mechanisms involved in such mRNA movement are yet to be elucidated, one obvious benefit from such exchange of mRNAs between two genetically distinct graft partners would be increased diversity of the genetic information accessible to both shoots and roots as a consequence of grafting.

What this means: These findings have important practical applications for grape breeding by enabling breeders to make the whole plant more productive and adaptive to disease and climate variation.

Indicator 6: During 2016, ARS will develop more effective methods to enhance biotechnology for crop improvement.

Altering expression of genes allows development of crops with improved agronomic performance and reduced environmental impact. Several approaches using biotechnology to alter gene expression have been developed; however, some of these methods rely only on non-native (transgenic) genes. ARS researchers in Ames, Iowa, have developed an approach called Proxy Selection in which traditional breeding methods are used to select for altered expression of a non-native gene. As a consequence of this selection, the expression of a native gene similar to the transgene gene is altered in a predictable way as well. The changes to native gene expression are maintained in the absence of the non-native gene. Thus, researchers have demonstrated a new method to produce non-transgenic plants with specific alterations in gene expression to investigate gene expression and help understand how genes function to produce valuable traits.

What this means: This method uses a combination of biotechnology and traditional breeding and may have utility in developing improved non-transgenic crops.

Lignin is the major structural component of plant cell walls whose presence and composition influences the usability of plant biomass for the production of biofuels and other natural products. ARS scientists in Lincoln, Nebraska, discovered a protein, SbMyb60, that activates synthesis of lignin in sorghum. Experiments showed that increasing the amount of SbMyb60 activated nine genes that increased lignin levels in sorghum biomass. SbMyb60 is the first activator of lignin synthesis to be identified in grasses.

What this means: SbMyb60 represents a tool to modify plant cell wall composition and has the potential to improve biomass for renewable uses in sorghum and other bioenergy grasses.

Indicator 7: During 2016, ARS will develop crop production strategies to optimize crop genetic potential, mitigate losses due to biotic and abiotic stresses, and increase production efficiency.

The scarcity of water in California is compelling growers to identify new water sources for irrigating crops. ARS researchers in Davis, California, demonstrated that municipal wastewater treatment produced water acceptable for irrigating grapes. The treated water also did not increase soil salinity, which is a major problem for agriculture in California. Irrigating grapes with treated water did not have any perceived effects on wine sensory characteristics. Wineries and vineyard operators will need to ensure their treated wastewater will have acceptable quality for irrigation.

What this means: Reuse of wastewater provides a way to produce grapes of high quality that will sustain and enhance the wine industry of California while supporting conservation of limited freshwater resources.

Small fruit growers are facing serious water limitations due to warmer and drier weather conditions, increased regulations, and greater demands for water by other sectors. Last year alone, the small fruit industry lost an estimated $20 million of fruit in the Pacific Northwest due to heat and inadequate supplies of water for irrigation and cooling. ARS scientists in Corvallis, Oregon, in collaboration with scientists at Oregon State University, found that growers could safely stop irrigating their blackberry fields after harvest. Withholding irrigation after harvest has no subsequent effect on yield or fruit quality of blackberry, which is a perennial crop, but can save growers 67,000 gallons of water per acre each year. The strategy also helps the plants to harden off in the fall and reduces the potential for freeze damage to the crop over the winter.

What this means: These findings provide growers with a new approach to water management that considerably reduces production costs and improves stewardship of limited water resources.

Indicator 8: During 2016, ARS will improve pollinator health, bee systematics and germplasm lines, and pollination.

Honey bees and other pollinators often are exposed to fungicides that are applied to plants in bloom where bees are collecting nectar and pollen. Fungicides control fungal growth on the plant by inhibiting basic cellular functions that are shared among broad ranges of organisms. Specifically, the fungicide Pristine prevents fungal growth by inhibiting cellular respiration and reducing the production of adenosine triphosphate (ATP), a molecule that animals use to convert food into energy. ARS researchers in Tucson, Arizona, found that field-relevant concentrations of Pristine fed to honey bees in pollen inhibited ATP production. Lower bee ATP levels could explain previously reported effects of Pristine on protein digestion and immunity in honey bees since ATP is essential in metabolic pathways associated with these physiological processes.

What this means: The effect of Pristine in honey bees indicates that this fungicide might not be safe for pollinators when applied where bees are foraging.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 3.1

During FY 2017, 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 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.

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 2016 PERFORMANCE REPORT FOR GOAL 3.2 - ACCOMPLISHMENTS

Indicator 1: During 2016, 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.

Reniform nematodes are roundworms that cause significant economic loss to cotton each year. Because new races of nematodes frequently infest cotton, breeders are continuously seeking new sources of resistance. The USDA National Plant Germplasm System (NPGS) contains more than 1,600 types of cotton seed that may contain resistance, but it would be time-consuming and costly to screen all of them. ARS researchers in Stoneville, Mississippi, used genome-wide DNA sequencing data to compare 375 varieties of Asiatic cotton germplasm from the NPGS and found resistance to reniform nematode in 122 varieties.

What this means: As lines of cotton with various genes for nematode resistance continue to be identified, the DNA sequencing data will be used to develop DNA markers that can be used to more rapidly transfer the resistance genes to upland cotton.

Fusarium wilt of watermelon is an economically significant disease. ARS researchers in Charleston, South Carolina, developed seed from two Fusarium-resistant varieties of watermelon, USVL246-FR and USVL252-FR, and have distributed them to more than 20 seed companies for evaluation. Several companies have found the new lines to be more resistant than other breeding lines currently in use, and two companies have begun using these resistant lines in their own breeding programs.

What this means: These highly resistant watermelon lines will provide strong protection against the damaging Fusarium wilt disease and will prove very useful to the U.S. watermelon industry.

The potato psyllid is the vector for the pathogen associated with zebra chip disease of potato, which renders potato tubers unmarketable. Wild potato germplasm contain favorable genetic traits, including insect resistance, which can be bred into marketable potato cultivars. ARS researchers in Wapato, Washington, and Sturgeon Bay, Wisconsin, screened populations of a wild potato species, *Solanum verrucosum*, for resistance to potato psyllid and discovered two populations highly resistant to the psyllid.

What this means: These populations will be used by breeders to develop new cultivars resistant to potato psyllid, which would provide a cost-effective control of the potato psyllid and zebra chip pathogen without insecticides.

Indicator 2: During 2016, 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.

The voracious gypsy moth is a devastating pest that is rapidly spreading across the United States. It defoliates millions of acres of hardwood forest annually, often in U.S. urban greenscapes. ARS scientists in Beltsville, Maryland, used gypsy moth RNA to develop technologies for creating RNA interference (RNAi)-based molecular biopesticides specifically designed to deactivate and silence genes crucial to gypsy moth survival. Gypsy moth caterpillars that consumed these compounds were less able to reproduce.

What this means: These highly specific biopesticide technologies will be useful tools for controlling gypsy moth pests and protecting U.S. trees from infestations, while sparing non-target insects.

Yellow nutsedge is a significant weed in Arkansas rice, and it is controlled by frequent use of the herbicide halosulfuron (sulfonylurea). Halosufuron belongs to a class of herbicides that target essential acetolactate synthase (ASL) plant proteins and eventually kill the plant. In 2012, halosulfuron failed to control yellow nutsedge when it was applied at the field rate specified on the product label. ARS scientists from Stoneville, Mississippi, and cooperators examined the resistance level, cross-resistance, and resistance mechanism in samples of the resistant weed and found that it was resistant to halosulfuron application rates that were 256 higher than field dose levels. The resistant plants also survived treatment with seven other ALS-inhibiting herbicides at labeled field rates. The scientists found that the ALS enzyme from the resistant plant was 2,540 times less responsive to halosulfuron than a susceptible plant, and that resistance appeared to be conveyed by a mutation that resulted in a single amino acid substitution in the ALS enzyme. Their findings confirm that a single, target-site mutation conferred a high degree of resistance in yellow nutsedge and a cross-resistance to other ALS-inhibiting herbicide families.

What this means: These findings provide researchers with information needed to develop effective herbicides for controlling this resistant strain of yellow nutsedge.

Significant variability in disease intensity exists among regions and cultivars affected by almond leaf scorch disease in California, the only State that produces almonds commercially. ARS researchers in Parlier, California, evaluated *Xylella fastidiosa,* the bacterium that causes leaf scorch disease on almond trees grafted onto four rootstocks. One rootstock, 'Nemaguard', a rootstock widely used because of its resistance to nematodes, promoted complete pathogen elimination and remission of leaf scorching symptoms, which indicates that an *X. fastidiosa*-resistant trait exists in the rootstock.

What this means: By using the 'Nemaguard' rootstock, growers in California are expected to be able to maintain a low disease incidence in their newly planted almond trees.

Indicator 3: During 2016, 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.

Wheat blast disease is a major threat to wheat production in South America, where it was first reported 30 years ago. The disease had not been detected outside of South America until spring 2016, when it was found in Bangladesh. This discovery confirmed the potential is high for the disease to spread to other wheat-producing countries, including the United States. ARS researchers in Frederick, Maryland, developed a diagnostic assay specific for the fungal pathogen that causes the disease, *Magnaporthe oryzae Triticum* pathotype (MoT), and used it to identify and characterize the isolates obtained from the first outbreak of wheat blast in Bangladesh. ARS scientists compared the genomes from 4 MoT isolates with those of 16 *M. oryzae* isolates collected from 10 different host species. The end result was the identification of a marker, MoT3 that can differentiate MoT isolates from other *M. oryzae* isolates.

What this means: The assay could be useful to government, academic, and private diagnosticians for detecting and identifying MoT isolates, and for monitoring outbreaks of wheat blast disease.

Ralstonia solanacearum is a bacterium that causes millions of dollars of losses in a wide range of crops. One strain in particular, the r3b2 subgroup, is such a threat to U.S. agriculture that it has been designated a select agent, and new regulations require that all strains of the bacteria be considered select agents until they are shown not to be r3b2. To prevent the r3b2 strain from entering the United States, ARS researchers in Beltsville, Maryland, developed a new molecular assay that improves the specificity and confidence in detecting the r3b2 subgroup of the pathogen. The new assay allows for quick, easy, and reliable detection and differentiation of the r3b2 strains of *R. solanacearum.*

What this means: The technology has been transferred to the USDA Animal and Plant Health Inspection Service as a general assay tool and is being used in two portable analysis formats for the rapid and accurate detection of this devastating bacterial pathogen.

The shot hole borer transmits *Fusarium* dieback, a serious plant disease affecting the California avocado industry. The shot hole borer was first detected in Florida groves in 2012 and increasing populations have resulted in tree damage comparable to damage in California. While conducting research on attractants for red ambrosia beetles in avocado groves, ARS scientists in Miami, Florida, discovered that a-copaene attracts the shot hole borer. Further research determined that a-copaene and quercivorol, a current shot hole borer lure, are equally as attractive to the insect and that a combination of the two chemicals results in significantly higher beetle capture.

What this means: ARS scientists and collaborators are using the new lure in Miami-Dade County avocado production areas to determine the prevalence of this new pest. Researchers will continue to evaluate the efficacy and longevity of this new two-component lure for shot hole borer.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 3.2

During FY 2017, 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 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.

GOAL AREA 4: ANIMAL PRODUCTION AND PROTECTION

The ARS Animal Production and Protection (APP) national programs provides 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 2016 PERFORMANCE REPORT FOR GOAL 4.1 - ACCOMPLISHMENTS

Indicator 1: During 2016, 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.

The efficiency of conversion of feed to milk (production efficiency) is a major factor affecting how the U.S. dairy industry impacts the environment, economics, and food supply of the country. Dairy cows vary in milk production efficiency, but only part of the variation among cows is explained by cow genetics. Dairy cows also have different communities of microbes in their rumens. In an effort to determine how rumen microbial differences affect production efficiency, ARS researchers in Madison, Wisconsin, and collaborators performed near-total exchange of rumen contents between high- and low-efficiency cows, and showed that these exchanges respectively decreased or increased milk production efficiency of each cow for about 7 days before returning to their previous levels. Additionally, after the rumen digesta exchange, the species composition of the rumen bacterial community gradually returned to a composition similar to the original unique profile of each host cow. The results directly implicated the rumen bacterial community as determinants of milk production efficiency.

What this means: Improvement of milk production efficiency with its concomitant decrease in environmental impact and improvement in farm return over feed costs may be possible if factors controlling the rumen microbial community can be optimized.

Litter size in swine is a component of the efficiency of the breeding herd. Previous studies indicated that glucosamine supplementation beneficially altered placental development, but subsequent studies on commercial sows indicated that glucosamine had equivocal effects on litter size. ARS researchers in Clay Center, Nebraska, in collaboration with an industry partner, demonstrated that supplementation of sow gestation diets with 20 grams (0.7 ounces) of glucosamine per day during the last trimester of pregnancy increased litter size by more than 1 piglet per litter born alive. The increase in litter size did not reduce average birth weights or preweaning survival.

What this means: Supplementation of sow diets with glucosamine during late pregnancy would contribute to improved reproductive efficiency in sow herds and improved profitability of swine production.

Indicator 2: During 2016, 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.

Liver abscesses are found at processing in approximately 13 percent of cattle being fed high-energy density rations, as this diet makes them more susceptible to infection from rumen bacteria that generate acid conditions in the digestive tract. The acidosis and associated liver abscesses seldom result in outward clinical signs, but reduce carcass weight and quality, and cost the processor $20 to $80 per affected animal in lost revenue. The prevalence of abscesses will likely increase as the use of antibiotics for promoting growth decreases. Also, because the abscesses are not outwardly detectable, there is a need for alternate management practices to prevent them. ARS researchers in Clay Center, Nebraska, identified 35 genetic markers associated with abscess susceptibility and detailed their study in a peer-reviewed journal.

What this means: These genetic markers may be useful in genetic selection programs to reduce the incidence of liver abscesses.

Genome studies in livestock species have made significant advances in eliminating deleterious mutations and improving production traits difficult or expensive to measure. These studies were made possible by the reference livestock genome sequence assemblies that were made in the preceding decade, but further improvements would increase the utility of the genome sequences. ARS scientists in Beltsville, Maryland, and Clay Center, Nebraska, working in tandem with members of the National Human Genome Research Institute, BioNano Genomics, Phase Genomics, and the PirBright Institute (based in the United Kingdom) have used the latest long-read sequencing technology available at Clay Center to create and release an improved reference genome assembly of the domestic goat. The new assembly filled most of the gaps in the previously public reference genome.

What this means: The improved reference genome is supporting advances in genome analysis and identification of key DNA variations by ARS and collaborator scientists.

Indicator 3: During 2016, ARS will develop and improve sustainable production systems for food animals; incorporating strategies to optimize production system efficiency while ensuring economic and environmental sustainability.

The chemical composition of forages consumed by dairy cattle affects feed intake and milk production, as well as the composition of manure and its impact on the environment. Improvements in the efficiency of feed nitrogen use and reduced urinary nitrogen loss can reduce feed cost and the environmental impacts of milk production. ARS researchers in Madison, Wisconsin, determined that feeding polyphenolic-containing forages, such as birdsfoot trefoil and red clover, and tannin extracts to lactating cows enhanced the efficiency of feed nitrogen use by the cow and reduced the excretion of urea in urine. This, in turn, reduced losses of ammonia and nitrous oxide (the most potent agricultural greenhouse gas) from dairy farms. This information has been highlighted in important popular press outlets and was featured in an international symposium, spurring ongoing tannin research internationally.

What this means: Feeding tannin extracts to dairy cattle can reduce ammonia emissions from barn floors by as much as 30 percent and from soils after manure application by as much as 50 percent.

The use of alternative protein sources in fish feed continues to increase as concerns persist surrounding the availability and cost of using ocean-harvested fish as protein and oil in fish feed. Furthermore, commercial farms are beginning to use land-based systems that recirculate water and allow production of market-size Atlantic salmon with less disease and without perceived negative effects on the marine ecosystem. Researchers at the Conservation Fund's Freshwater Institute in Shepherdstown, West Virginia, showed that a novel fishmeal-free diet fed to Atlantic salmon in recirculation aquaculture systems resulted in greater waste production, but equal salmon growth, feed conversion, and survival compared with a traditional fishmeal-based diet. These findings were adapted to larger-scale salmon production, for which ARS provided the first evidence that Atlantic salmon can be effectively raised to market size while consuming a fish meal-free diet in a commercially relevant land-based system.

What this means: This research provides strategies for infrastructure and rearing that are expected to increase Atlantic salmon production efficiency and reduce reliance upon capture fisheries.

Indicator 4: During 2016, ARS will characterize nutrient requirements of food animals; measure nutrient availability of traditional and nontraditional feedstuffs; and develop strategies for improving nutrient use efficiency.

Fish oil is derived from capture fisheries, such as sardines and menhaden, and has been the traditional source of omega-3 fatty acids in feeds for farmed fish, such as trout. However, the limited availability of fish oil from natural resources is currently limiting the expansion of aquaculture production, which aims to provide healthy protein sources to a growing global population. ARS researchers in Aberdeen, Idaho, determined the nutrient digestibility, palatability, and functionality of a number of new commercial sources of algae that are high in omeaga-3 fatty acids. All algal products exhibited high digestibility of omega-3 fatty acids, with no effect on feed intake, and minimal effect on feed manufacturing.

What this means: Identifying alternative sources of omega-3 fatty acids for aquaculture feeds that do not reduce production efficiency or product quality, such as these algae, will decrease our dependence on ocean-harvested fish and remove production barriers to increasing the availability and sustainability of this heart- and brain-healthy food.

The farm-raised catfish industry has the highest total economic value of any domestic aquaculture industry; in 2013, 605 farms produced more than 350 million pounds of food-sized fish valued at more than $350 million. Fish feeds constitute half the cost of production; therefore, understanding the nutrient requirements of this fish is essential to maintain the competitiveness of this industry. Catfish feeds are plant-based and can feature high levels of phytate or phytic acid, a compound that binds iron and other minerals, making them unavailable to fish. ARS scientists in Auburn, Alabama, and Stuttgart, Arkansas, collaborated with colleagues at Auburn University and demonstrated that coating feed with the enzyme phytase, which destroys phytate, could boost the uptake of iron and other key nutritional minerals. Scientists also showed that fish given the phytase-treated diet had higher red blood cell and hemoglobin counts, increased growth rates, and a greater ability to convert iron and other minerals in the digestive tract into useable forms that can be deposited into the blood stream. Phytase is currently used in poultry and swine diets to destroy phytate.

What this means: These results suggest that phytase-amended diets could improve both the health and production of farmed catfish.

Feeding high-quality protein to ruminants to improve growth efficiency is limited in utility because rumen microorganisms degrade amino acids, making them unavailable and also increasing the release of ammonia to the environment. Reducing the excretion of ammonia would reduce the environmental impact of the herd. Biochanin A, a phytoestrogen derived from red clover, inhibits hyper-ammonia producing bacteria that degrade protein and adversely affect amino acid profiles entering the small intestines. ARS scientists in Lexington, Kentucky, conducted a grazing experiment with steers feeding on pastures of mixed cool-season grasses. Adding biochanin A to a dried distillers grain protein supplement as part of the animals' feed significantly increased average daily weight gain over the pasture-only control treatment. Additionally, Biochanin A inhibition of hyper-ammonia producing bacteria increased cellulolytic bacteria, which might play a role in increasing ruminal degradation of fiber.

What this means: Biochanin A benefits animal performance by improving the quality of digested protein and digestion of dietary fiber.

Indicator 5: During 2016, 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.

Improving the eastern oyster through genetic selection and breeding is expected to make the oyster more economically feasible to produce on a commercial basis. ARS scientists in Kingston, Rhode Island, and their collaborators conducted field trials to evaluate the growth, mortality, and yield of six mass-selected oyster populations at five farm sites with varied environmental conditions. Significant genetic and environment interactions were detected for mortality and yield, and peak mortality at each site and coincided with the most prominent oyster pathogen at that site. Selected varieties generally performed best at their native site, and some varieties exhibited above average performance at multiple sites.

What this means: Characterization of interactions between oyster varieties and the environments in which they are raised will enhance current breeding efforts that aim to increase production efficiency and profitability of shellfish farming while improving the quality and availability of shellfish products to U.S. consumers.

Hybrid catfish created by mating blue and channel catfish are the preferred fish produced by the U.S. farm-raised catfish industry, which relies primarily on the D&B and Rio Grande strains of blue catfish. ARS scientists in Stoneville, Mississippi, examined the influence of blue catfish sire strain (D&B vs. Rio Grande) on hybrid catfish embryo production and fingerling performance under commercial hatchery conditions. Average testis weight, an indicator of reproductive efficiency, was higher in Rio Grande fish compared with that of D&B fish. However, D&B hybrids exhibited higher rates of mean survival, production, and growth efficiency compared with Rio Grande hybrid catfish fingerlings reared in earthen ponds.

What this means: This research demonstrates the potential of exploiting genetic differences between strains to increase production on commercial farms.

Prior to development of the genomics component of the Animal-GRIN (Germplasm Resources Information Network), the livestock research community did not have a mechanism to permanently store genotypes derived from publically funded livestock genomics work. As a result, the long-term security of expensive data was at risk and it was difficult for other researchers to access and leverage this information in other experiments. An ARS-led team developed a genomics component as part of Animal-GRIN Version 2. With this component, it is possible for public sector researchers to enter their genomic data into the database and for the community at large to have access to those genotypes. The developed component also makes available, for the first time, the linkage and access to genomic, phenotypic, management, and environmental information complete with a physical tissue sample from the individual animal.

What this means: This work opens up public data to a broad range of users so they have the opportunity to leverage previous investments made in genotyping.

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 4.1

During FY 2017, 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

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.

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

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.

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.

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 2016 PERFORMANCE REPORT FOR GOAL 4.2 - ACCOMPLISHMENTS

Indicator 1: During 2016, ARS will describe 5 new discoveries or developments significant for their scientific or applied value.

Foot-and-mouth disease virus (FMDV) is the most infectious disease of animals and affects food security in much of the world. Unfortunately, a key challenge in the control of FMDV is that 50 percent of vaccinated cattle become persistently infected. Persistent FMDV infections in cattle are largely responsible for the massive depopulation of animals because of the fear these animals, although asymptomatic with no clinical signs, may spread FMDV and infect other animals. Very little is known about the mechanisms that lead to this reinfection. ARS scientists in Orient Point, New York, found that the divergence between carrier animals and FMDV-free animals occurs as early as 10 days after infection. Microscopic localization of the virus indicated persistent infection of specific regions of the nasopharyngeal mucosa.

What this means: These findings provide new insights into paths that may be taken to develop vaccines that could prevent animals from serving as carriers of FMDV to unvaccinated animals. Having a vaccine to prevent FMD-persistent infections would support the implementation of a "vaccine to live" strategy and eliminate the needless slaughter of vaccinated animals.

In 2006, a case of atypical bovine spongiform encephalopathy (BSE-H) was diagnosed in a cow with a heritable genetic mutation in the bovine prion protein gene (PRNP). Unlike classical BSE, which is caused in cattle that eat contaminated BSE material, it is thought that atypical BSE cases may occur spontaneously in cattle due to genetic mutations in the PRNP. ARS scientists in Ames, Iowa, conducted a series of pathogenicity studies and showed that the survival time of the cattle with the genetic mutation and inoculated with BSE-H was shorter (10 months) than cattle without the mutation (18 months). This genetic effect was not observed when cattle with or without the genetic mutation were inoculated with classical BSE. Their survival time was 26 months, regardless of whether or not the cattle carried the genetic mutation.

What this means: The results of these studies demonstrate that the genetic mutation associated with atypical BSE exhibits a number of features that differ from classical BSE. Understanding the association between this genetic mutation and BSE provides important information on the potential public health risk of atypical BSE.

The capability of larvicide sprays to penetrate into buildings or through vegetation where mosquitoes may be resting or hiding is not well known. ARS researchers in Gainesville, Florida, in partnership with the Florida Army National Guard, investigated the efficacy of liquid larvicide against mosquitoes that are responsible for the spread of Zika, chikungunya, yellow fever, and dengue viruses. The scientists compared spray applications of a larvicide that targets mosquitoes in a simulated urban environment to mimic conditions in Florida, a hot-arid desert environment as one would find in California, and a dry-season tropical environment typical in Thailand. Results indicated poor penetration into buildings and vegetation in all three environments, even when sprayed at point-blank range.

What this means: These field trials demonstrate that it may not be possible to effectively control these mosquitoes with traditional methods, but instead, they will require new techniques and formulations.

Indicator 2: During 2016, 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.

The loss of ecological species barriers, which permits opportunistic pathogens to cause disease in wildlife (i.e., animals that are not susceptible to an infectious agent provide a natural barrier for other animal species), is a major factor influencing disease emergence in wild birds. ARS scientists in Athens, Georgia, in collaboration with University of Georgia scientists, found vaccine-derived Newcastle disease viruses (NDV) from different species of wild birds across four continents from 1997 through 2014. The data indicate that at least 17 species from 10 avian orders occupying different habitats excrete vaccine-derived NDV. Examining the extent of spillover of live vaccines, such as NDV, from poultry into wild birds is crucial because the downstream epidemiological consequences of such spillovers are still unknown. Circulating live vaccine viruses could present additional risks, such as reversion to virulence and recombination with wild-type strains. In addition, the immune response of wild birds induced by infection with vaccine strains may result in greater virulence.

What this means: The finding of live attenuated NDV in other avian species provides important evidence that the use of these vaccines should be monitored to assess their potential effect on the environment and the emergence of new viral strains.

Significant economic losses from poultry death and decreased egg production have resulted from infections caused by H9N2 low-pathogenic avian influenza virus (LPAIV) across North Africa, the Middle East, and Asia. This group of viruses has also caused sporadic infections in mammals, including humans, and has been associated with some specific genetic changes that suggests increasing pandemic potential. The H9N2 LPAIVs have been endemic in Pakistani poultry since 1996, but no new viruses had been reported since 2010. Because novel genotypes of Pakistani H9N2 contain mammalian host-specific markers, ongoing surveillance is essential to better understand any continuing public health risk. ARS scientists in Athens, Georgia, in collaboration with Pakistani scientists, reported this year the characterization of four new H9N2 LPAIVs, three found in 2015, and one found in 2012. All of the viruses tested in this study originated in the Middle East. Importantly, these viruses all contained mammalian host-specific markers, suggesting that Pakistan avian H9N2 viruses have the capacity to infect mammals.

What this means: This information underscores the continued need to undertake surveillance in poultry and mammals to monitor the spread of these and other influenza strains and understand the potential for zoonotic infections.

The imported fire ant quarantine has been in place since 1958, regulating the interstate movement of certain commodities in an effort to reduce the spread of imported fire ants. Rapid ant identification at border inspection stations and ports is critical to facilitate trade and commerce. A significant problem is that it is not always possible to identify fire ants because few specimens are collected and it is difficult to identify native and imported ants by physical examination. Researchers with ARS in Gainesville, Florida, and their APHIS colleagues in Biloxi, Mississippi, have developed a field-portable, rapid detection kit to identify imported fire ants. The kit requires no special training or equipment and takes only 10 minutes to confirm whether the ants are imported fire ants.

What this means: APHIS plans to use the kits at interdiction sites to more efficiently enforce the quarantine. In addition, regulatory agencies from other countries are interested in adopting the technology.

Indicator 3: During 2016, 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.

A DNA codon is a series of three nucleotides that maintain the codes for specific amino acids, which are the building blocks of proteins. Some amino acids have more than one codon, and some codons are used more often than others. This tendency to use a particular codon is called codon bias and can vary between microorganisms and their animal hosts. ARS scientists in Orient Point, New York, determined that the E2 glycoprotein, a determinant of virulence of classical swine fever virus (CSFV), had a similar codon bias as pigs, its natural host. They explored the effect of switching the native codons in E2 for less frequently used codons for the pig. Their studies showed that the genetically altered CSFV no longer caused disease. Although this phenomenon is still a subject of investigation, it is thought to occur because a changing codon affects the ability of a gene to be translated into protein. Interestingly, when ARS scientists explored the potential use of this phenomenon to generate a vaccine strain, they found the altered virus was able to protect animals against the disease. By using synonymous but less active codons and not changing a single amino acid in the virus product, this potential vaccine leaves all natural antigenic epitopes intact.

What this means: The benefits of producing vaccines using these genetic alterations is that the antigenic profile of the virus remains intact, which is important for inducing a protective immune response. Additionally, by changing the nucleotide composition, genetic markers are now available that could be used to differentiate between vaccinated and infected animals.

Traditional methods of vaccinating poultry often involve an operator entering the poultry house to spray vaccine using a backpack-mounted device, which increases the likelihood of pathogens being inadvertently brought into the barn and thus, greater biosecurity risks. Although vaccines are often added to poultry water supplies, contamination can also occur when this method of vaccination is used. To solve these problems, ARS scientists in Mississippi State, Mississippi, developed a new, fully automated system for spraying vaccines inside poultry barns. The system triggers birds to drink from water locations using changes in lighting. After the birds approach a water source, vaccine spray nozzles are lowered from the ceiling and the birds are sprayed. The nozzles are strategically placed above the water source to ensure the birds receive maximum coverage. The target is the animal's eye area, where scientists know that vaccines are easily absorbed, but birds will also pick up the vaccine through preening and contact with other birds. The scientists compared the performance of the automated system against a three-person vaccination crew with backpack sprayers using a combination of infectious bronchitis and Newcastle disease vaccines. The results of blood samples taken from automatically vaccinated flocks showed improved immune protection against the viruses compared with the backpack method.

What this means: Biosecurity risks and the number of personnel required to vaccinate a flock were both reduced, while immune protection was improved.

Edwardsiella ictaluri is the causative agent for enteric septicemia of catfish, a highly fatal systemic infection that is responsible for significant economic losses in the catfish industry. Researchers from Mississippi State University in collaboration with ARS scientists in Stoneville, Mississippi, conducted commercial field trials with a previously patented oral vaccine to prevent septicemia. Vaccination was shown to dramatically improve fish production, resulted in improved animal health and growth rates. In 2015, more than 90 million fingerlings were vaccinated on six commercial operations.

What this means: In commercial fish farms, trials increased gross sales by approximately $3,000 per acre for channel catfish and $2,000 for hybrid catfish (i.e., a 30 percent to 50 percent increase over sales for non-vaccinated fish populations).

FY 2017-2019 PERFORMANCE PLAN FOR GOAL 4.2

During FY 2017, ARS will:

1. Describe 5 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 2018, ARS will:

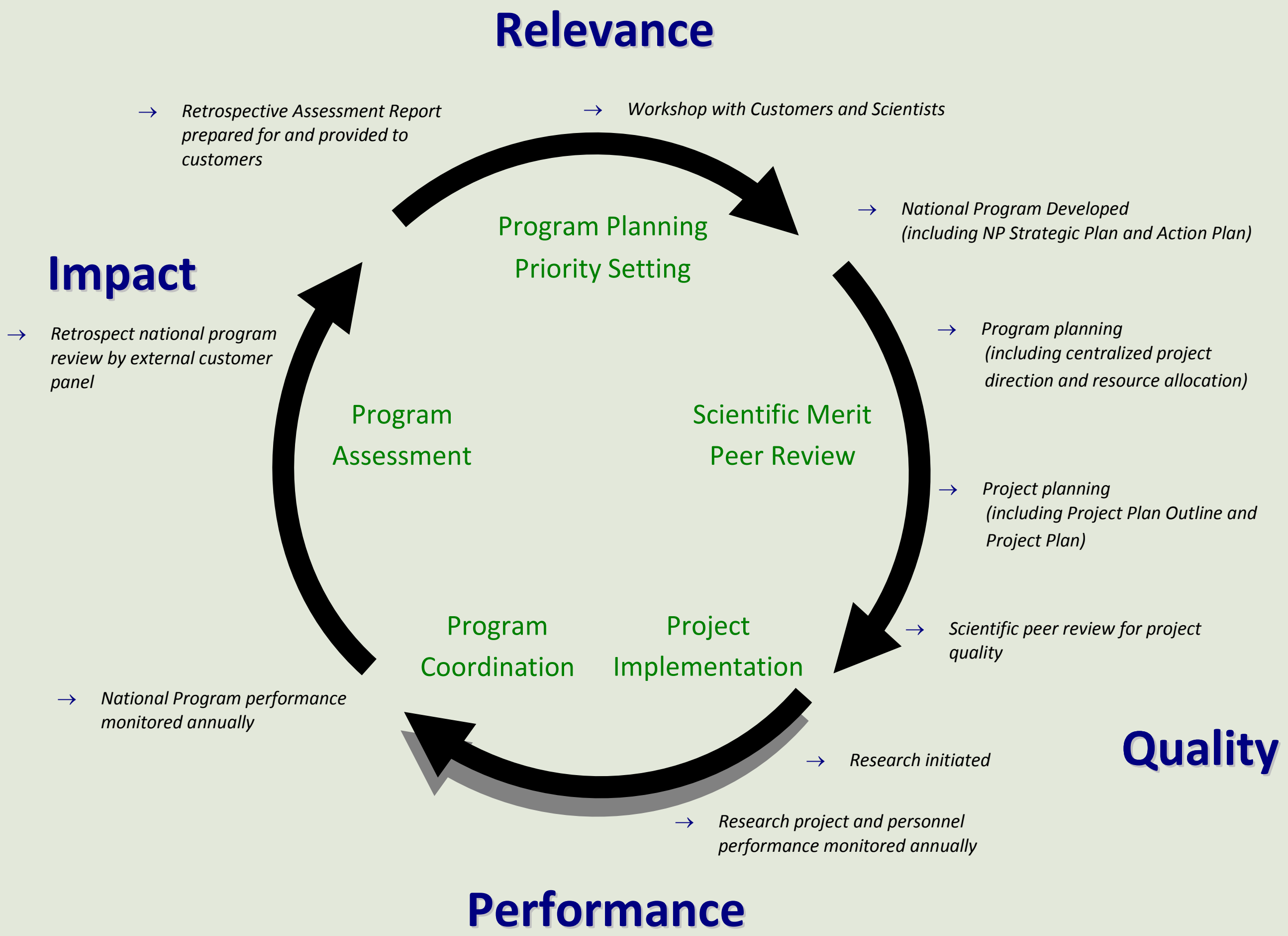
1. Describe 5 new discoveries or developments significant for their scientific or applied value.
2. Form new partnerships and continue old partnerships with industry, universities, and other government agencies in order to promote production and marketing of new methods for detection and identification 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

APPENDIX 1 - NATIONAL RESEARCH PROGRAM MANAGEMENT IN ARS

Approximately 690 research projects from around the country are aligned into 17 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. Nearly 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 - 173

Algeria	2	**Ghana**	9	**Nigeria**	14
Burkina-Faso	1	**Guinea-Bissau**	1	**Rwanda**	4
Burundi	2	**Kenya**	21	**Senegal**	3
Cameroon	3	**Madagascar**	1	**Sierra Leone**	1
Central African Republic	2	**Malawi**	10	**South Africa**	30
Cote D'Ivoire	1	**Mali**	3	**Tanzania**	12
Democratic Republic of the Congo	2	**Morocco**	6	**Tunisia**	2
Egypt	12	**Mozambique**	6	**Uganda**	8
Ethiopia	10	**Namibia**	2	**Zambia**	4
Gambia	1				

Return to Collaborations map.

Collaborations with Countries in Asia - 488

Afghanistan	1	**Kuwait**	1	**South Korea**	56
Armenia	1	**Malaysia**	4	**Sri Lanka**	2
Bangladesh	5	**Mongolia**	3	**Syria**	1
China	194	**Nepal**	3	**Taiwan**	18
Georgia	2	**Pakistan**	18	**Tajikistan**	1
India	20	**Palestine**	1	**Thailand**	9
Indonesia	7	**Philippines**	10	**Turkey**	25
Israel	29	**Russia**	17	**Ukraine**	1
Japan	33	**Saudi Arabia**	3	**Uzbekistan**	4
Jordan	4	**Singapore**	3	**Vietnam**	7
Kazakhstan	5				

Return to Collaborations map.

Collaborations with Countries in Central and South America - 306

Argentina	37	**Ecuador**	8	**Nicaragua**	3
Bolivia	4	**El Salvador**	2	**Panama**	4
Brazil	113	**Guatemala**	4	**Paraguay**	2
British West Indies	1	**Haiti**	3	**Peru**	13
Chile	7	**Honduras**	6	**Trinidad and Tobago**	1
Columbia	14	**Jamaica**	2	**Uruguay**	8
Costa Rica	14	**Mexico**	60		

Return to Collaborations map.

Collaborations with Countries in Europe - 617

Albania	2	**Greece**	17	**Portugal**	5
Austria	19	**Hungary**	6	**Romania**	4
Belgium	23	**Ireland**	14	**Serbia**	5
Bulgaria	1	**Italy**	64	**Slovakia**	3
Czech Republic	6	**Lithuania**	3	**Slovenia**	2
Denmark	21	**Luxembourg**	3	**Spain**	71
Finland	10	**Netherlands**	51	**Sweden**	15
France	62	**Norway**	10	**Switzerland**	26
Germany	67	**Poland**	12	**United Kingdom**	95

Return to Collaborations map.

Collaborations with Countries in North American -107

Canada	106

Return to Collaborations map.

Collaborations with Countries in Oceania - 98

Australia	72	**New Zealand**	23	**Papua New Guinea**	3

Return to Collaborations map.