Charles Valentine Riley Memorial Foundation

Food, Agriculture and Natural Resources Research

Agricultural Research Service: Specialized Agency Functions and University Relationships

Contents

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About the Charles Valentine Riley Memorial Foundation

The Charles Valentine Riley Memorial Foundation (RMF) is committed to promoting a broader and more complete understanding of agriculture and to build upon Charles Valentine Riley's legacy as a "whole picture" person with a vision for enhancing agriculture through scientific knowledge. RMF, founded in 1985, recognizes that agriculture is the most basic human endeavor and that a vibrant, robust, food, agricultural, forestry, and environmental-resource system is essential for human progress and world peace. RMF's goal is to have all world citizens involved in creating a sustainable food and agriculture enterprise within a responsible rural landscape.

RMF's Commitment for Increased Federal Research Investment

RMF supports growing each of the key components of the agricultural research funding portfolio that supports the national system delivering results for the public good: **competitive grants,** which take advantage of innovation at public and private universities, and other organizations with scientific and technical expertise; **capacity funds**, for state (universities) and federal agencies such as USDA's Agriculture Research Service, Economic Research Service and Forest Service, to continue to provide a stable scientific workforce and research sites that conduct research requiring long-term commitment and potential high-risk/high-payoff solutions, while maintaining the capacity to rapidly deal with crisis situations**;** and **public-private partnerships**, such as the Foundation of Food and Agricultural Research, a nonprofit corporation that matches public funds with private funds to conduct research on problems of national and international significance.

About this Report

RMF sponsored the development of this report highlighting the special and unique functions of the Agricultural Research Service (ARS) because of its commitment to further agricultural research. RMF believes a strong agricultural research program in the United States is essential to the long-term national interest, and a strong national program is built on a combination of intramural and extramural scientific programs. Even though ARS is the major intramural research arm of the USDA, this agency is perhaps less known or recognized for its work than extramural performers — public and private — of agricultural research. The RMF believed a clear explication of the unique and critically important roles ARS plays was warranted, and an emphasis on how ARS both complements and strengthens the research conducted by others.

Disclaimer

Although RMF supports increased investment in food, agricultural and natural resources research and education, that message is not the intent of this report. The primary purpose of this report is to document what is being done with existing resources. Where quotes are included, the source is provided. These quotes do not necessarily reflect the position of RMF.

Highlights

The Agricultural Research Service (ARS) is the largest of the U.S. Department of Agriculture's (USDA) intramural research agencies. ARS fulfills some uniquely federal responsibilities to benefit and maintain the food, agricultural and natural resources of the United States and, in accomplishing these, maintains relationships with universities. By co-locating laboratories on or near university campuses, ARS taps into faculty and student expertise to help fulfill its federal responsibilities while simultaneously building capacity throughout the country. Other USDA intramural research and statistical agencies — Economic Research Service (ERS), National Agricultural Statistics Service (NASS), Forest Service (FS) — and the extramural research agency, the National Institute of Food and Agriculture (NIFA), play important, complementary roles. All agencies participate in the development of the USDA strategic plan, and articulate research priorities and contributions to the overall research effort in the Science Roadmap and REE Action Plan, as called for by Congress[2]

What distinguishes ARS research from discovery-driven, more fundamental research pursued in universities is its mission orientation. Because some food and agricultural research requires long periods of time, specialized expertise and/or facilities, ARS has taken on responsibilities to maintain the long-term infrastructure needed to conduct its mission-oriented research, and that also serve as a resource to the broader scientific community located in academia and the private sector. Most can be thought of as uniquely federal scientific responsibilities because universities and private companies are not able to maintain the long-term specialized facilities, trained personnel and continuous funding needed to sustain these essential functions. These specialized functions include:

- Development and maintenance of collections
- Response to emergencies
- Support of USDA action agencies and other federal agencies
- Technology transfer
- Unique locations, specialized lab facilities and premier information sources
- International programs and foreign laboratories

ARS research units at 75 locations are on or near land-grant and non-land-grant university campuses and provide opportunities for cooperation and synergy in research and education. The extent of that cooperation is reflected in the numerous university appointments held by ARS scientists, and the numbers of students participating in undergraduate, graduate and post-graduate training and educational experiences.

In 2014, ARS scientists held 1,096 university appointments, mentored 306 post-doctoral and 631 doctoral students, and supervised 1,125 undergraduate students working in ARS labs. ARS scientists are co-located with university and other partners in many configurations—on campus in university facilities, on campus in federal facilities, in ARS facilities off campus but nearby, and in third party facilities. These arrangements facilitate the synergistic interactions among scientists from the universities and ARS and provide an opportunity to share facilities and equipment. These also facilitate the sharing of genetic and other collections and data resources that have been assembled by ARS scientists over long periods of time.

Nationwide accomplishments of ARS-university cooperation. This report includes descriptions of accomplishments, listed below, that feature ARS cooperation with 11 universities. It also includes three long-term, multiple-location projects where up to 60 universities are involved.

Predicting seed longevity in genebanks
Estimating evapotranspiration (ET) by remote sensing
Elevated carbon dioxide (CO2) levels and length of growing season
Crop adaptation to extreme environments
New technology and nematode resistance in potatoes
New apple rootstock with tolerance to apple replant disease
Genetic enhancement of maize
Cropping system impacts on nutrient concentrations in soil and water
Perennial filter strips to protect water
Corn stover harvest and reduced nutrient concentrations
Cytokines as an alternative to antibiotics
New cotton germplasm resistant to cotton leaf curl virus
Herbicide rotations and herbicide resistance in agricultural weeds
Reducing ginning costs by improving ginning efficiency
Changes in catfish diets and feeding regimes
High-yielding drought-tolerant soybean cultivars
Spoilage of acidified vegetables by Bacillus
Peanut butter improved by using encapsulated peanut skins
"Clean" berry crops free of targeted pathogens
Land use practices and stream and river water quality
New farm-scale gasifier unit for creating value-added products
Enhancing nutrition of soybean meal
Mitigating phosphorus loss ensures safe drinking water
Tear staining in pigs as an indication of stress
Transition to alternative cropping systems to require less water
Management of the Ogallala Aquifer
Increased seed numbers in sorghum
Yeast supplementation and the well-being of stressed calves
High quality, cold-tolerant grass variety and improved grazing systems
Reducing phosphorus loss on dairy farms
Potato clones resistant to both late blight and early blight
Parenting practices and improved vegetable consumption by toddlers
Rice consumption and better adult nutrition
Absorption of vitamin D when taken with a meal
Fast-food restaurant menu items impact on chronic disease
Understanding normal biological pathways and reducing cataracts
Blood levels of zinc in the aging

The 35 specific examples help to illustrate the richness and diversity of achievement made possible by ARS-university scientific cooperation and for the purpose of benefiting agriculture, food and nutrition, consumers and society.

Foreword

Over the course of my career, I have had the opportunity to work with and observe ARS from almost every possible vantage point – as an ARS scientist, as an external scientific advisor, as a Federal regulatory agency client, as a private sector research partner, as a university partner with multiple ARS laboratories on campus, and as the Under Secretary with responsibility for its oversight – and I have come to appreciate the need for the services it provides. I have come to admire the men and women who plan and conduct its ambitious and far-reaching research agenda. I have also come to learn that very few individuals grasp the full extent of the special and very necessary roles that ARS plays.

The Agricultural Research Service (ARS), the intramural research agency of the U.S. Department of Agriculture, is a major contributor to agricultural scientific advances in the United States and globally. With nearly 2,000 scientists and almost 8,000 employees in total, ARS research fulfills some uniquely federal responsibilities, partners with universities and the private sector, and provides research infrastructure and services important to agricultural researchers. This paper describes the six special roles ARS plays in the American agricultural research system and provides examples of the many ways it partners with universities to further scientific knowledge and train the next generation.

ARS's six unique roles are long-term and mission-driven. These include emergency response, developing and maintaining collections, direct research support to the regulatory and "action" agencies of the Federal government, technology transfer, international programs and foreign laboratories, library and digital services, and maintaining unique laboratory facilities. These roles are federal responsibilities because neither the private sector nor universities are able to maintain the long-term specialized facilities, trained personnel and continuous funding needed to carry them out over time.

Because most ARS laboratories are located near or on a university campus, they bring expertise and facilities to their partner universities and provide training opportunities for undergraduates, graduate students and post-doctoral scientists. In recent years, ARS has employed over 1,000 undergraduates, 600 graduate students and about 300 postdoctoral students annually.

The collaborative and complementary partnership between ARS and universities has been enormously beneficial to American farmers and to all Americans, yielding a continuous stream of innovations that provide solutions for farmers and abundant food for the consuming public. It is a distinctive partnership, noteworthy in its design and innumerable contributions, and should be strengthened and celebrated.

— **Catherine E. Woteki**, President, Charles Valentine Riley Memorial Foundation; Professor of Food Science and Human Nutrition, Iowa State University; and Former Undersecretary for Research, Education and Economics, U.S. Department of Agriculture

Introduction

Congress provides funds to the U.S. Department of Agriculture (USDA) to undertake research to benefit and maintain the food, agricultural and natural resources of the United States. These funds supporting research and education reflect a unique partnership between the federal government and the states that can be traced to decisions made under Presidents Washington, Adams and Jefferson, and formalized in the Morrill Act enacted by Congress and signed into law by President Lincoln.

Today USDA priorities for agricultural research center in four agencies within its Research, Education and Economics (REE) mission area. Three of the four are intramural agencies: The Agricultural Research Service (ARS), Economic Research Service (ERS), and National Agricultural Statistics Service (NASS)[1]. The fourth agency, the National Institute of Food and Agriculture (NIFA)[2], is responsible for funding university-based research and education through competitive programs and for administrating capacity funding for institutions of higher education as defined by Congress. Research also is conducted by the U.S. Forest Service (FS)[3] under USDA's Natural Resources and Environment mission area.

Over the last 240 years, the agricultural research system in the United States has continued to evolve to meet the nation's needs for food, fiber and feed, and to partner with other countries and international organizations to respond to agricultural emergencies and build the knowledge base for global food security.

A unique aspect of the U.S. system is that almost equal shares of the research funds appropriated to USDA go to intramural agencies and extramural organizations. Extramural research funds are directed primarily to universities. USDA distributes a portion of the extramural funds to land-grant universities on a formula basis for capacity purposes, while other extramural funds are distributed through competitive grants. Both the intramural research programs and the capacity funds recognize the need for long-term, sustained investments in research that address the place-based nature of agriculture. USDA's intramural and extramural programs are complementary, and the intramural programs serve uniquely federal responsibilities. Over the years, strong relationships have developed between the intramural agencies and the universities where research programs are conducted and supported. This special report focuses on the ARS, the largest of USDA's intramural research agencies. It describes the uniquely federal responsibilities

[1] ERS anticipates trends and emerging issues in agriculture, food, the environment and rural America, and conducts high-quality, objective economic research to inform and enhance public and private decision making. NASS conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. Production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use and changes in the demographics of U.S. producers are only a few examples. Thus, NASS provides timely, accurate and useful statistics in service to U.S. agriculture.

[2] NIFA provides leadership and extramural funding for programs that advance agriculture-related sciences. It invests in and supports initiatives that ensure the long-term viability of agriculture and applies an integrated approach to ensure groundbreaking discoveries in agriculture-related sciences and technologies reach the people who can put them into practice.

[3] FS Research & Development conducts highly integrated research at all scales — watershed, landscape, regional, and national — to address problems of environmental and social concern. Scientists provide knowledge and tools to managers and decision-makers to assist in the sustainable management and use of our nation's natural resources.

of ARS and its relationships with universities, emphasizing the roles ARS laboratories play in fulfilling their federal responsibilities while simultaneously building capacity.

While this special report focuses on the role of ARS intramural research in the overall U.S. effort in food, agricultural, and natural resources, it is important to emphasize the other USDA intramural research and statistical agencies — ERS, NASS and FS — and the extramural research agency, NIFA, play important, complementary roles and that their work is closely coordinated to avoid overlap and duplication. Indeed, there are numerous jointly planned and administered projects that draw on the expertise and resources each agency brings to a problem. All agencies participate in the development of the USDA strategic plan, and articulate research priorities and contributions to the overall research effort in the Science Roadmap and REE Action Plan, as called for by Congress.[4]

Over its history, ARS has accrued functions vital to the support and defense of U.S. agriculture and are of a nature universities cannot provide. These functions, including specialized laboratory facilities, also provide a resource and service to the scientific community in universities and sister agencies. These specialized functions include the development and maintenance of collections, emergency response, direct research support to the regulatory and "action" agencies, technology transfer, international research engagement and maintenance of biocontrol laboratories in foreign countries, and the National Agricultural Library (NAL).[5]

In its ranks, ARS has the experienced scientific intellectual capacity and physical infrastructure to respond to immediate challenges to agriculture. For well over a century, ARS has worked in geographically and climatologically diverse areas of the country, allowing its scientists to draw upon historically relevant and currently maintained data and resources. The agency conducts research to solve emerging and technical problems of broad scope and high national priority. Research covers a wide range of critical problems affecting American agriculture and the nation as a whole. ARS conducts research to inform program and regulatory decisions made by other USDA agencies. It provides research of value to federal agencies outside USDA that affect American agriculture. ARS research supports international efforts and responsibilities in food and agriculture.

ARS employs nearly 2,000 scientists and a total of 8,000 other employees who support the scientific mission. ARS carries out approximately 690 research projects at more than 90 locations around the nation and in foreign countries. Some are public destinations, such as the National Arboretum located in the nation's capital, which is both an ARS research facility dedicated to ornamental plants, and a garden open to the public.

The ARS mission is to develop and transfer solutions to agricultural problems of high national priority to:

- Ensure high-quality, safe food and other agricultural products
- Assess the nutritional needs of Americans

[4] Readers are encouraged to visit the websites for these agencies to learn more about each of them.

[5] NAL is one of four national libraries of the U.S. government and the nation's major information resource on food, agriculture and natural resource sciences. With its vast holdings of agricultural literature and new data services, NAL also is a global resource.

- Sustain a competitive agricultural economy
- Enhance the natural resource base and the environment
- Provide economic opportunities for rural citizens, communities and society
- Provide the infrastructure necessary to create and maintain a diversified workplace

ARS research is managed through 17 national programs and priorities within the broad areas of:

- Crop production and protection, emphasizing genomics and genetic improvement, and identifying plant diseases and challenges from pests.

- Animal production and protection, emphasizing food animal production; combating animal diseases; promoting animal and human health; special developments in veterinary, medical and urban entomology; and aquaculture.

- Natural resources and sustainable agricultural systems, emphasizing water resources and watershed management; pasture, forage and rangeland development; impacts of drought and salinization; climate change and impacts on soils and emissions; the technological development of biorefined products and other industrial and agricultural byproducts; and the examination of agricultural sustainability and systems.

- Nutrition, food safety and quality, emphasizing the study of nutrition and its impacts on the well and those who may be health compromised or challenged; food safety relative to plants and animals and especially on zoonotic diseases that cause human and animal illnesses; and continuing emphasis of nutritional impacts and food safety as contributors to quality and utility of agricultural products.

As a scientific organization supported by taxpayers, ARS works to ensure its research is relevant, shared in the scientific community and made available to society as a whole.

This report describes ARS's unique and specialized functions and includes descriptions of sites where ARS research units are co-located with universities, providing specific examples of how ARS participates in training the next generation of scientists. The 11 locations were selected to represent different regions of the country, and to represent co-locations with land-grant and non-land-grant public universities and private universities.

Specialized Agency Functions

Although all of the ARS intramural research is conducted within a broad structure of both public and private research, some of the functions that require specialized expertise and/or facilities are highlighted.

Collections

Throughout ARS's history and that of its predecessors, scientific collections have played an important role in agricultural research. One major national collection dates back to 1881 when the USDA's Chief Entomologist Charles Valentine Riley was named Honorary Curator of Insects at the Smithsonian Institute. In 1982, much of USDA's insect collection was moved into the National Natural History Museum.

ARS maintains extensive scientific collections that serve as definitive resources for agricultural research. The collections have supplied the basic materials for crop improvement, helped in the identification of invasive species, and played an important role in the documentation of global biodiversity. The types of collections include plant germplasm, culture (living organisms), specimen-based (preserved), and non-organism (chemical or molecular reagent) collections. The collections of living materials require highly specialized conditions, including those needed for isolated reproduction of organisms. The collections are available to university scientists and others who have the expertise to properly handle the materials.

ARS collections include bacteria, fungi, nematodes, parasites, vertebrate protozoa, viruses (vertebrate and invertebrate), cell cultures, plant viruses and viroids, germplasm (vertebrate and invertebrate), invertebrate systematics, plant genetic resources (including genetic stocks), chemicals and molecular reagents.

The value of the collections becomes strikingly apparent after a disease outbreak or other major incident affecting agriculture. Many times, ARS collections have been used to help identify invasive species and settle economically important international trade disputes and quarantine issues.

Purpose of Collections

In general, the size, scope and fiscal support for collections are strongly associated with their roles and objectives. A brief description of a number of collections is provided.

National genetic resource collections are maintained to preserve essential genetic materials (species, varieties, lines) for research and genetic improvement. Samples are distributed worldwide.

Core systematic or reference collections are maintained for systematic and taxonomic research, and critical to the continuity of specific scientific disciplines. Specimens are available worldwide to support research.

Research collections are assembled by individual units as resources for in-house ARS research. These collections often are small and not intended for widespread distribution. Scientists usually provide access to these collections upon request from other researchers.

Examples of Widely Used Collections

National Plant Germplasm System. The National Plant Germplasm System is one of the largest and most important distributors of germplasm in the world. The system comprises more than 20 genebanks throughout the United States, which conserve germplasm of grain, vegetables, sugar crops, oilseeds, fruits, nuts, beans, ornamentals and other crops. Over 13,000 species are represented by over 5,000,000 accessions. These resources provide the essential genetic materials to support research and genetic improvement of crops worldwide. The system is widely recognized as pivotal to global food security. Genebank resources are accessible online through the Germplasm Resources Information Network (GRIN), a database documenting accession numbers, locality data, associated vegetation, data on key agricultural traits and more relevant information for each accession. GRIN makes germplasm materials available free of charge to researchers and breeders in search of genes for product quality and for resistance or tolerance to pathogens and environmental stresses. GRIN-Global is a more recent development, partly funded by global non-governmental organizations, that provides GRIN resources in multiple language indices, permitting researchers around the world to learn about genetic materials that may be helpful to their work. Prominent collections within the National Plant Germplasm System include:

- National Small Grains Collection
- USDA Soybean Germplasm Collection
- National Cotton Germplasm Collection
- U.S. Potato Genebank
- National Clonal Repository for Temperate Fruit, Nut and Specialty Crops
- Five Regional Plant Introduction Stations

Culture Collection. The ARS Culture Collection is the world's largest publicly accessible collection of microorganisms and is officially registered with the World Data Center for Microorganisms. This collection of bacteria and fungi, maintained in Peoria, Illinois, serves as an international reference of microbial germplasm for agriculture, biotechnology and medicine. Holdings are accessible to researchers worldwide through an online database. The collection also supports ARS research projects in microbial genomics and bioprocessing at the National Center for Agricultural Utilization Research in Peoria. Accessions in the ARS Culture Collection include 19,000strains of bacteria, 60,000 strains of fungi and 6,000 patent cultures.

Examples of Systematic and Research Collections

National Entomological Collection. This collection is the second largest insect collection in the world, with approximately 35 million specimens and 300,000 species. It is managed and used as a joint effort between ARS and the National Natural History Museum.

Nematode Collection. The collection is the nation's premier repository of fixed specimens of plant and insect nematodes. Established in 1960, the collection is recognized as one of the

world's largest and most valuable resources for nematode research. The materials in the collection are used by researchers around the world for systematics research and identification of parasitic nematodes. The collection, maintained by the USDA Nematology Laboratory in Beltsville, Maryland, contains 40,000 nematode species.

Protection and Preservation of Bee Germplasm. ARS's honey bee collection in Beltsville, Maryland, is an example highlighting the importance of maintaining smaller, research-oriented holdings. Colony collapse disorder, the phenomenon of unexplained bee losses, became widespread throughout the United States in 2006. Preliminary research suggested a new pathogen, the Israeli acute paralysis virus, was to blame. Some experts hypothesized the virus entered the country in 2005 when a ban on Australian bee imports was lifted. Therefore, they recommended the ban be reinstated. But after studying samples from the Beltsville bee collection dating back to when the ban was still in effect, ARS researchers found the virus species had already been present in the United States at least two years before the ban was lifted. Because of this scientific finding, the ban was not reinstated.

Response to Emergencies

Emergency situations emerge that may reasonably be presumed to threaten U.S. agriculture and the food supply. One of the functions of ARS and its capacity to respond is to provide immediate expertise and resources. For instance, when microorganisms (fungi, bacteria or viruses) evolve or mutate to endanger plants and animals, ARS provides immediate attention and analysis. Likewise, when exotic organisms invade the United States, the scientific infrastructure made possible by capacity funding is necessary to respond immediately and minimize any adverse impacts. The infrastructure includes having available high-security ARS laboratories to study potentially highly injurious foreign organisms.

The threats posed by a fungus, an insect pest and two viruses are provided as examples of emergency actions that greatly reduced the economic damage that could be caused.

Highly Pathogenic Avian Influenza Vaccine

The Highly Pathogenic Avian Influenza outbreak in 2014 and 2015 was the worst animal disease outbreak ever experienced in the United States, sweeping across 15 states and forcing officials to kill nearly 50 million birds. Consumers felt the economic impact as egg prices increased by 50.6 percent and egg shortages were experienced. In support of USDA Animal and Plant Health Inspection Service (APHIS), ARS scientists within weeks had developed a rapid molecular test to detect the virus and quickly engineered a vaccine using a new reverse genetics technology. That's the importance of discovery when Americans need it. ARS scientists are considered among the most experienced and skilled in the world regarding this virus and are often called upon to respond to avian influenza outbreaks throughout the world.

Rift Valley Fever Virus

Rift Valley Fever is a potentially fatal viral disease in humans that is transmitted by mosquitoes. The virus also can negatively impact livestock health. Though the Rift Valley virus is largely

restricted to Africa, experts are concerned it could be introduced and established in the United States. In laboratory studies, ARS scientists in Gainesville, Florida, evaluated eight species of mosquitoes commonly found in the United States for their ability to transmit the virus. They found some species of mosquitoes have a greater ability to transmit the virus than others, a finding that has a direct impact on the risk assessment of disease transmission to humans and livestock. The results will allow mosquito control assets to target the species most likely to be involved in disease transmission if disease ever appears in the United States.

Ug 99 Strain of Wheat Rust

ARS is committed to global efforts combating wheat rust diseases threatening U.S. crops and food supplies. Wheat rust is a fungus that also can infect barley and rye. An especially tough strain, Ug99, was discovered in Uganda in 1999. Ug99 is a threat to up to 80 percent of the global wheat supply, including the U.S. crop. It is highly contagious and spreads quickly through the air. U.S. scientists are searching for wheat strains naturally resistant to Ug99. These resistant varieties then can be crossed with local varieties, making them resistant when Ug99 moves in. The research effort already has discovered resistant plants, and testing crosses is underway to see if these are as productive as current varieties. The ARS Cereal Disease Research Laboratory in Minnesota is a major player in the global effort against Ug99 and is working in partnership with U.S. Agency for International Development.

Brown Marmorated Stink Bug

The brown marmorated stink bug, a native to Asia, was discovered in Allentown, Pennsylvania, in 2001. Since then it has devastated orchards, crops and fields, and become a terrible nuisance in gardens, backyards and homes. The pest has an appetite for up to 300 different plants. Estimates of economic damage vary, but in 2010 it was blamed for causing an estimated $37 million in apple losses in the Mid-Atlantic region alone. The bug has spread to more than 40 states and parts of Canada. Scientists in the ARS Invasive Insect Biocontrol and Behavior Laboratory developed a pheromone and trapping system for the brown marmorated stink bug for use in orchards and other sites. They recently deciphered pheromones to attract other stink bugs, opening the door to development of improved traps and technologies that will help keep invasive pests out of backyards, gardens, homes and agricultural operations.

New World Screwworms

ARS's decades-long expertise was called upon in 2016 to address an outbreak of New World screwworms in Florida Key deer on Big Pine Key. This was the first U.S. infestation reported in 30 years. The screwworm is devastating for cattle ranchers. It caused tens of millions of dollars in losses annually before it was eradicated from the United States in 1966 — using a technique developed by ARS scientists. ARS researchers developed the sterile fly technique that involved releasing sterilized (infertile) screwworms into infested areas, where they would mate with wild screwworms without producing progeny. ARS and USDA APHIS continue to collaborate on a fly-rearing facility in Panama that is supplying sterile flies today to create a barrier in Central America to prevent the spread north of screwworm populations still persistent in South America. In Florida, ARS scientists, working with APHIS and the Florida Department of Agriculture and

Consumer Services, brought in nearly 154 million sterile flies from the Panama facility and released them in the Keys and southern Florida. By April 2017, five months after the infestation was discovered, APHIS announced the screwworm had been successfully eradicated from Florida.

USDA Action Agencies and Other Federal Agencies

ARS performs research of value or of critical need for other USDA agencies and other federal agencies. ARS research supports the USDA action agencies of Animal and Plant Health Inspection Service (APHIS), Natural Resources Conservation Service (NRCS), Food Safety Inspection Service (FSIS), Food and Nutrition Service (FNS), and Agricultural Marketing Service (AMS).

Examples of ARS Support of USDA Action Agencies

Guarding against citrus greening. Citrus greening, a plant disease also known as Huanglongbing, costs citrus growers millions of dollars annually. Once present only in Florida, the disease has spread to parts of Texas and California. The disease is the most serious threat in the history of the U.S. citrus industry. ARS researchers are developing new strategies to combat this devastating disease, including introducing an improved diagnostic test to detect the responsible bacterium. This bacterium is transmitted from plant to plant by the Asian citrus psyllid, and reliably detecting and identifying the bacterium is crucial for preventing citrus greening outbreaks. ARS designed the assay test currently used to detect the disease in citrus groves. Agency supported: APHIS

Improving soil and water conservation and agricultural production. ARS scientists, in collaboration with USDA NRCS, have made significant enhancements to the world's leading simulation model for assessing the watershed-scale environmental effects of crop, forest and rangeland management. The Soil and Water Assessment Tool (SWAT), originally developed by ARS scientists, is a critical part of the Conservation Effects Assessment Project, through which USDA evaluates the regional and national effects of conservation practices. The new model includes improved data structures and data analysis, a new web-based interface and improved representation of critical agricultural production regions. Congress, USDA agencies and international decision-makers rely on this state-of-the-art tool to support natural resource management and conservation practices and to help shape agricultural policy. Agency supported: NRCS

New analytical method for assessing nitrosamines. Nitrosamines are cancer-causing compounds that can be formed by nitrites or nitrates. Nitrosamine levels in fried bacon were a major concern 30 years ago before steps were taken to reduce their formation. However, nitrosamine levels have not been monitored since the 1990s. The USDA Office of Inspector General requested FSIS conduct a survey of nitrosamine formation from cooked bacon and an accompanying risk assessment to check if the situation had changed. The previous analytical methods used for nitrosamines were unwieldy and used archaic specialized equipment that was unavailable. At the request of FSIS, ARS scientists in Wyndmoor, Pennsylvania, developed and validated a new,

sensitive, rapid and easy-to-use test for assessing nitrosamine levels in fried bacon. Agency supported: FSIS

Making progress in preventing child obesity. The childhood obesity rate has more than doubled among children and quadrupled among adolescents over the past 30 years. Over one-third of children and adolescents are overweight or living with obesity. Obesity early in life leads to lasting problems related to health as well as psychosocial problems, ultimately resulting in much greater risk of chronic disease as an adult, decreased productivity and increased costs of health care. ARS research on childhood obesity prevention has provided important insights to guide development of educational and behavioral interventions. Agency supported: FNS

Beef carcass grading camera system to predict meat tenderness. Because variation in the tenderness of beef results in consumer dissatisfaction, companies want technology to help predict and identify carcasses that excel in tenderness. ARS scientists in Clay Center, Nebraska, worked with an instrument manufacturer and the beef industry to develop a robust regression equation for a beef grading camera system, which obtained approval from USDA AMS to predict tenderness at the time of beef carcass grading. The technology gives the beef industry a way to measure USDA quality grade and yield based on grade and tenderness — all with the same instrument. Agency supported: AMS

Value of ARS Research to Other Federal Agencies

Here are examples of federal agencies outside of USDA benefiting from ARS research: Department of Defense (DOD), mosquito management; National Institutes of Health (NIH), nutrition; Department of Energy (DOE), bioenergy; Food and Drug Administration (FDA), food safety; U.S. Geological Survey, natural resources and climate; National Aeronautics and Space Administration (NASA), remote sensing and land use; Environmental Protection Agency (EPA), minor use pesticides and efficacy; and U.S. Agency for International Development (USAID), crop germplasm and specific projects on common bean and tepary bean.

Technology Transfer

The Agricultural Research Service (ARS) has been delegated authority by the Secretary of Agriculture to administer the patent program for ARS, the review of cooperative research and development agreements and the technology licensing program for all intramural research conducted by USDA. The agencies involved include ARS, Forest Service (FS), Animal and Plant Services (APHIS) and nine additional USDA agencies.

Technology Transfer Process

USDA broadly defines technology transfer as the adoption of research outcomes (i.e., solutions) for public benefit. Although a seemingly simple statement, the process of adoption is complicated, requiring integration of many assets from disparate sources in the successful delivery of solutions. Public benefit is achieved through many mechanisms, including public release of information, tools and solutions (e.g., germplasm, plants and other materials); adoption and enhancement of research outcomes by partners through collaborative research; formal cooperative research and development agreements (CRADAs) authorized by the Federal Technology Transfer Act (1986); direct federal, state or local technical assistance; or through licensing of biological materials or protected intellectual property directly to not-for-profit entities and for-profit, private-sector firms.

Successful adoption of USDA knowledge and research outcomes typically require complementary assets and services provided by multiple agencies in USDA, including agencies that are not primarily engaged in direct research in the physical and life science arena. Private sector involvement in technology transfer adds the benefits of creating new or expanded businesses, jobs and economic prosperity. Science-based innovations from USDA intramural research, often developed through public-private partnerships, create new or improved technologies, processes, products and services that benefit the nation by increasing productivity, increasing efficiency (keeping costs low) and enhancing global competitiveness for the U.S. agricultural sector. Thus, technology-transfer functions are critical to accelerating utility of public research and development investments and creating economic activity, including job creation and sustainable economic development.

Outcome Metrics

The following metrics, taken from the USDA FY2016 Annual Report on Technology Transfer (**https://www.ars.usda.gov/ARSUserFiles/ott/USDA%20FY2016%20TT%20Rpt.pdf**), provide a useful perspective on recent outcomes from technology transfer activities:

Numbers for ARS, APHIS and FS, FY2016	
New inventions disclosed	244
Patent applications filed	109
Active licenses	441
Income bearing licenses	439
Active CRADAs	238
Other collaborative R&D agreements*	11,854

** Other collaborative R&D agreements include: Trust Fund Cooperative Agreements, Reimbursable Agreements, Material Transfer Research Agreements, Specific Cooperative Agreements and Non-Funded Cooperative Agreements, Challenge Cost-Share Agreements, Collections Agreements, Cooperative Agreements, Inter-agency & Intra-agency Agreements, Joint Venture Agreements, Participating Agreements, Research Cost-Reimbursable Agreements, Research Joint Venture Agreements)*

	Numbers for ARS
License income	$4,784,000
Earned royalty income	$3,633,000
Total income	$8,417,000

Examples of Transferred Technologies

Examples of technologies that have been transferred or that are in the process of being transferred include:

- Reducing nitrosamines in food
- Effective insect repellents
- Producing low-fat cheese
- Improved frozen food quality
- First blueberry hybrid
- First small turkey
- Instant mashed potatoes
- Sourdough bread
- Process for lactose-free milk
- Turn old tires into zinc fertilizer
- New flour from grape seeds
- Method for identifying harmful bacteria
- Improved soil nitrogen test
- New process for pasteurizing shelled eggs
- Fate of nutrients during grain processing
- Portable processing facility for fish
- Improved citrus rootstocks
- Bacteriological assay for salmonella
- Improved rice flour batter
- Moisture meter for in-shell peanuts.
- Durum wheat with soft grain
- Transfer of cotton gin technologies

Details can be found at USD ARS Tech Transfer Success Stories, **https://www.ars.usda.gov/office-of-technology-transfer/tech-transfer-success-stories/**, and in the FY 2016 Annual Report on Technology Transfer for the Agricultural Research Service, **https://www.ars.usda.gov/ARSUserFiles/ott/ARS%20FY2016%20TT%20Rpt.pdf**.

Unique Locations, Specialized Facilities and Premier Information Sources

Unique Locations

Beltsville Agricultural Research Center. ARS's headquarters at the Beltsville Agricultural Research Center in Maryland is the largest concentration of agricultural research scientists in the world. With its close proximity to the nation's capital and other federal scientific agencies, the center conducts a wide range of research, and frequently hosts scientific delegations from other countries.

Regional Research Centers. Four regional research centers dedicated to finding new uses for agricultural commodities are located in Wyndmoor, Pennsylvania; New Orleans, Louisiana; Peoria, Illinois; and Oakland, California. These laboratories have made enormous contributions to improving daily life through research, which has led to technologies as disparate as mass production of penicillin to no-iron cotton to the spectrophotometer, a ubiquitous workhorse

instrument in chemistry labs everywhere. The centers focus on the needs of contemporary agriculture and the public need for innovative new uses of agricultural products.

Specialized Facilities

ARS is developing two state-of-the-art animal disease research facilities — one in Athens, Georgia, and on in Manhattan, Kansas. In Athens, ARS is modernizing the biocontainment facilities and expanding the capabilities of the ARS Southeast Poultry Research Laboratory, the preeminent location for poultry-related disease, toxicology and food safety research. In Manhattan, the new National Bio and Agro-Defense Facility will allow ARS and USDA APHIS to safely study foreign animal and zoonotic diseases, such as foot-and-mouth disease of cattle, classical swine fever, and African swine fever that are not yet in the United States. When completed in 2023, the facility will replace an aging facility on Plum Island, New York, which is currently the primary USDA laboratory responsible for research on high-consequence foreign zoonotic diseases, but which lacks the infrastructure to work at the highest biosecurity level.

Premier Information Sources

The National Agricultural Library in Beltsville, Maryland, is the world's largest agricultural library and one of four congressional national libraries. The library is an important component of the ARS research infrastructure and is rapidly increasing the ways in which information can be maintained, curated and shared with scientific colleagues. As a public institution, ARS maintains an open access policy for data and research results. The National Agricultural Library is instrumental in helping ARS meet that demand. The library provides access to nearly 50,000 peer-reviewed journal articles authored by USDA researchers through the PubAg public archive system and is adding more publications every year. It is a popular and active resource. In 2016, users downloaded more than 13.5 million full-text items. This free flow of information is an important stimulus for entrepreneurs, including those who will be developing valuable decision-support options for farmers based on site-specific crop, soil and weather data.

International Programs and Foreign Laboratories

Overview of International Programs

ARS has bilateral research agreements with Brazil, China, Israel and South Korea, and cooperative work with countries in Europe, Africa, South America, Australia and Asia. Much of the international research is conducted by scientists employed by overseas institutions in cooperation with ARS scientists in the United States.

Overseas Biological Control Laboratories

ARS operates laboratories in France, Australia and China that conduct research on potential biological pest control agents for use against invasive species, with emphasis on species invasive to the United States. These labs are closely linked to domestic ARS labs that evaluate potentially useful biological pest control agents. The overseas laboratories often host cooperators, visiting scientists, postdoctoral researchers and graduate students.

European Biological Control Laboratory (EBCL). The team is international and interdisciplinary, composed of seven scientists, five support scientists, five technicians and three administrative support staff. The facility is located on the Campus International de Montferrier-Baillarguet in Montpellier, France.

Australian Biological Control Laboratory (ABCL). The staff search natural areas of Australia and Southeast Asia for insects and other organisms that feed on pest insects and plant species that are invasive in the United States. Based in Brisbane, Queensland, the laboratory is hosted by the Commonwealth Scientific and Industrial Research Organization.

Sino-American Biological Control Laboratory (Sino-ABCL). The laboratory was established in 1990 through an extramural agreement between ARS and Chinese Academy for ARS and Chinese Academy for Agricultural Science (CAAS) in Beijing, China, in 1988.

Co-locations and Training Scientists

Co-location of ARS Research Units with University Campuses and Units

ARS conducts important long-term intramural research at numerous university campuses while cooperating with pertinent university scientists. In tandem with the flourishing of the land-grant universities established by the Morrill Act, ARS (and its scientific research predecessor in USDA) experienced growth in its scientific research mission on behalf of agriculture. This cooperative relationship has enabled continuity of long-term scientific research, maintenance of resources, training of scientists and the important presence of a cadre of state-based agricultural science experts when those areas are faced with immediate or emerging challenges. ARS also cooperates and partners with other non-land grant universities with compatible expertise.

The location of ARS research units on or near university campuses provides an excellent opportunity for cooperation. The extent of cooperation is reflected in the number of university adjunct or other professional appointments held by ARS scientists, and the number of undergraduate and graduate students and post-graduate scientists receiving training and education in ARS facilities. Of the 90 ARS locations, most are located on land-grant or non-land-grant university campuses and related centers. Co-location takes many configurations: on campus in university facilities, on campus in federal facilities, in nearby ARS national laboratories off campus and in third-party facilities. This arrangement facilitates synergistic interactions among scientists from the universities and ARS and provides an opportunity to share facilities and equipment. It also facilitates the sharing of genetic and other collections and data resources that have been assembled by ARS scientists over long periods of time.

Training the Next Generation of Scientists

While mentoring students and young scientists is not a primary function of ARS researchers, it is an important measure of the leadership and community stewardship ARS scientists have always demonstrated toward agriculture and related sciences. Each year ARS scientists bring hundreds of students, from high schoolers to those seeking graduate degrees and post-doctorate positions, into their laboratories to conduct research. They take part in experiments on animal and plant development, disease management or eradication, water resource management, new technologies and much more. Young students learn to feed and care for animals, help with fieldwork and provide substantive support to ARS research. They learn the research methods, procedures and discipline needed for a future in scientific discovery. A special ARS program involves early-career scientists from the historically black colleges so they can learn new research techniques and procedures as well as cutting-edge science in ARS labs that is of interest to them.

The following numbers from 2014 are useful in understanding the role ARS is playing in developing the next generation of scientists:

- 306 postdoctoral appointments funded by ARS
- 631 graduate students conducting research in ARS laboratories
- 1,125 undergraduate students working in ARS laboratories

University Cooperators and Selected ARS Accomplishments

"Agriculture Research Service scientists working within research university's communities allow USDA's applied mission and science to be fulfilled by the brightest young minds on the planet. That collaboration also creates a pipeline of scientists to tackle the next generation of agricultural problems."

— Edward S. Buckler, Research Geneticist, Agricultural Research Service, USDA, and Adjunct Professor, Plant Breeding and Genetics at the Institute for Genomic Diversity, Cornell University, recipient of the 2017 National Academies of Science Award in Food and Agriculture Sciences

The location of ARS research units on or near land-grant and non-land-grant institutions campuses and related centers provides an excellent opportunity for cooperation. In some cases, USDA owns and has maintained resources that benefit both ARS and the neighboring institutions by facilitating long-term research. The extent of that cooperation is reflected in the number of university appointments by ARS, and the number of those receiving post-graduate training and education and undergraduate students located in ARS facilities.

Specific information concerning cooperation is provided in this document by selecting locations in several states associated with a university location and providing the number of scientists, the number of adjunct or other appointments held by those scientists, and the facilities utilized at those locations. The ARS locations selected as examples represent different areas of the country, including mountain, northeastern, midwestern, southern, southeastern, northwestern, and southwestern states. Although much of the research has national implications, the environmental conditions vary considerably. Since nutrition research is less site-specific, the location of much of that research was determined primarily by the expertise in the university at that location.

In addition to the accomplishments provided earlier in connection with ARS's specialized functions, selected accomplishments are provided for each location. The numbers of accomplishments vary in relation to the number of scientists involved. Examples of accomplishments being reported are associated with the following universities:

- Colorado State University, Ft. Collins
- Cornell University, Ithaca, New York
- Iowa State University, Ames
- Mississippi State University, Stoneville
- North Carolina State University, Raleigh
- Oregon State University, Corvallis
- Purdue University, West Lafayette, Indiana
- Texas Tech University and Texas A&M University, Lubbock
- University of Wisconsin, Madison
- Baylor University and Tufts University, Houston and Boston
- Multiple Location Initiatives

Cooperating University: Colorado State University

ARS Program, Joint Appointments, and Facilities

ARS has 27 scientists located at or near Ft. Collins, Colorado, who are associated with Colorado State University. These ARS scientists conduct research on plant germplasm preservation, natural resources rangeland and agricultural systems. The ARS scientists hold 21 university adjunct appointments and 11 scientists serve in other appointed cooperative roles. ARS scientists are located in an ARS building on the university campus and the university provides maintenance. Space is made available for university scientists and students.

Selected ARS Accomplishments

Predicting seed longevity in genebanks. ARS has been collecting and preserving genetic materials since the 19th century. These materials have proven to be a boon for scientists in the 21st century as they develop means to use DNA to improve and modify plants. Colorado is one of the main depositories for such materials. By preserving seeds, genebanks can efficiently safeguard genetic diversity of thousands of species valuable to agriculture. But seed survival in genebanks varies considerably, creating challenges for effective genebank management, plus there are additional costs for implementing customized, idiosyncratic preservation treatments and monitoring changes in seed viability. To develop genebank management tools that are more effective and reduce costs, an ARS researcher in Fort Collins applied materials sciences approaches, more commonly used to evaluate plastics, to explain why some seeds die rapidly and others succumb at different rates during storage. This new, unified explanation provides a rational framework to optimize seed storage practices and to predict how long seeds can survive in genebank storage. The new approach will guide efforts to conserve more species as seeds, as well as reduce expenditures on germination tests that detect seed aging during long-term storage.

Estimating evapotranspiration (ET) by remote sensing. Advanced tools developed to estimate evapotranspiration (ET) by remote sensing imagery holds promise for remotely sensing crop water use, but further technological developments are needed to deliver tractable tools to accomplish this objective. ARS researchers in Fort Collins, Colorado, and Parlier, California, worked collaboratively with NASA to develop basic algorithms that allow remotely sensed satellite vegetation indices to be used to predict crop water requirements for individual fields and crops. These algorithms were combined with ground-based weather station data to predict water use on a daily basis for irrigated crops in California. Subsequently, NASA used these technologies to develop the Satellite Irrigation Management Support (SIMS) Decision Support System (DSS) for more than 10 million irrigated acres in California. This system can be used to increase irrigation efficiency in California, which is currently experiencing a severe drought, conserving valuable water supplies.

Elevated carbon dioxide (CO2) levels and length of growing season. Rangeland forage levels are changing because of climate warming, and more information is needed about these dynamics so management practices can be adjusted appropriately. In collaboration with Colorado State University researchers, ARS scientists in Fort Collins, Colorado, used a Free-Air CO2 Enrichment (FACE) system to study how elevated carbon dioxide (CO2) and temperature

affected the growing season for temperate grasses. FACE uses outdoor heaters and pipes in experimental fields to elevate air temperature and CO2 levels. Warming led to a longer growing season, because leaves emerged earlier in some plants and other plants died later in the season. Elevated CO2 levels also reduced plant water demand—a response that extended the growing season but did not change the reproductive season—which in turn increased plant life span. These results will improve the accuracy of models used to simulate plant growth and watershed changes under current and projected elevated CO2 concentrations and warming. The improved models, in turn, will help producers, rangeland managers, and others to generate appropriate management practices that incorporate ecosystem shifts associated with climate change.

Cooperating University: Cornell University

ARS Program, Joint Appointments, and Facilities

ARS has 27 scientists located at Ithaca, New York, who are associated with Cornell University. These ARS scientists conduct research on plants, soil, and nutrition and on emerging pests and pathogens. ARS scientists hold 21 university adjunct appointments and 19 scientists serve in other appointed positions. Seven ARS scientists are located in university facilities, two scientists are located in the Boyce Thompson Institute, which is also on the campus, and one scientist is located in Cold Spring Harbor. The remaining scientists are located in ARS facilities.

Selected ARS Accomplishments

Crop adaptation to extreme environments. Acidic soils constitute 40 percent of arable land in the tropics and subtropics. Aluminum (Al) toxicity in acidic soil stunts and damages root growth, resulting in significant reductions in crop yields due to nutritional deficiencies and drought stress. Rice is the most Al-tolerant of the major cereal crops. ARS and university scientists in Ithaca, New York, showed that rice tolerance to Al is due in part to a novel transporter gene (OsNRAT1) that promotes Al sequestration into the root cell vacuole. OsNRAT1 is sufficient for promoting Al transport in diverse systems from plants to yeast. This knowledge may allow the growing of target crops with Al tolerance in acidic soils using conventional breeding or transgenic approaches.

New technology and nematode resistance in potatoes. Potato cyst nematodes (PCNs) are devastating pests impacting the U.S. potato production, which is valued at $4 billion. Methods for effective PCN control are limited and often rely on toxic chemicals, so there is a major need to develop new methods to protect potatoes from these nematodes. ARS researchers in Ithaca, New York, have identified genes critical for nematode infection. They have employed a plant mediated RNAi technology to silence these nematode genes, which resulted in the development of a nematode resistant potato cultivar. This technology, which was patented, provides a valuable new tool for plant researchers working to protect potato growers and the industry from costly nematode losses.

New apple rootstock with tolerance to apple replant disease. Diseases affecting U.S. apple crops have been affecting yields and profits. ARS and Cornell University researchers in Geneva,

New York, have developed and released a new apple rootstock, named G.814, a dwarfing, productive, early bearing, and highly yield-efficient tree. It is the most recent product from a series of disease resistant and productive apple rootstocks developed by the Geneva breeding program. This rootstock is resistant to fire blight and crown rot, two diseases that infect apple trees with serious economic consequences. Most importantly, G.814 has shown tolerance to the apple replant disease complex. This rootstock was tested for 15 years to evaluate rootstock productivity levels and compared with standard cultivars. On the basis of preliminary trials in the United States, G.814 will increase production of larger, high-quality fruit in marginal replanted orchard land, which will help apple producers increase yields and profits.

Cooperating University: Iowa State University

ARS Program, Joint Appointments and Facilities

ARS has 85 scientists located at Ames, Iowa, who are associated with Iowa State University. These ARS scientists conduct research on corn insects, crop genetics, plant introductions, natural resources, agroecosystems, animal diseases, food safety, and enteric pathogens. The ARS scientists hold 57 university adjunct appointments, and 20 scientists serve in other appointed cooperative roles. A high percentage of the ARS scientists are located in university buildings while others are in a federal building on the university campus. Three scientists associated with the Ames location are in the Danforth Plant Sciences Center in St. Louis, Missouri.

Selected ARS Accomplishments

Genetic enhancement of maize. For more than 20 years, the USDA-ARS Germplasm Enhancement of Maize (GEM) project, stationed at Iowa State University, has taken valuable genetic traits from exotic maize found in countries around the world and made them available for use in the United States. GEM's mission is to release exotic-derived germplasm in a useable format adapted to the temperate United States — an essential step for discovery and utilization of valuable alleles and traits such as resistance to disease, insects and abiotic stresses, and amino acids, starch, oil and biofuels. Researchers from 61 public and private institutions have partnered in GEM to release 300 lines derived from exotic maize genetic resources using traditional breeding methods. Iowa State University and USDA-ARS researchers jointly released 204 doubled haploid maize lines from previously unsampled genetic material. International collaborators conducting disease-screening trials for pathogens not yet in the United States provide insights that will help U.S. breeders move rapidly, should these pathogens become established here. Other cooperating universities include Cornell University, Louisiana State University, North Carolina State University, North Dakota State University, Ohio State University, Texas A&M University, University of Delaware, University of Illinois, University of Nebraska, University of Tennessee, University of Wisconsin and Truman State University.

Cropping system impacts on nutrient concentrations in soil and water. Cropping systems have been developed that reduce the impacts on nutrient concentrations in soil and water. When fertilizers are applied to Midwestern row crops, some of the phosphorus and nitrate is lost from the soil and pollutes nearby waterways. Sometimes these nutrients are eventually transported to

large estuaries or lakes, where they help create oxygen-deficient "dead zones." Since nitrate losses beneath perennial crops such as alfalfa are known to be small, an ARS scientist in Ames, Iowa, conducted an investigation to see if nutrient losses associated with annual row crops in the Midwest could be reduced through changes in cropping systems. The scientist collaborated with Iowa State University researchers in an eight-year study to compare nutrient concentrations in soil water beneath different cropping rotations. Results indicated growing alfalfa and corn in rotation can reduce phosphorus losses, and that four-year rotations are the most feasible management option for farms that integrate crop and livestock production. These findings, which can be used to help moderate nitrogen and phosphorus losses from crop fields and optimize management practices, will benefit agricultural and conservation communities alike.

Perennial filter strips to protect water. Vegetative filter strips help manage nitrogen movement and protect the environment. Using nitrogen fertilizer in agricultural systems can result in emissions of the greenhouse gas nitrous oxide (N2O), plus nitrate (NO3) contamination of ground and surface waters from field runoff. ARS scientists in Ames, Iowa, studied the use of perennial vegetation filter strips in annual cropland watersheds as a means of reducing these losses. Vegetation filter strips placed at the base of slopes were found to be effective at decreasing NO3 losses to ground and surface waters. The strips removed NO3 from field runoff via plant uptake, immobilization into soil organic matter, and microbial denitrification within the filter strips. Denitrification was found to be the predominant NO3 sink, accounting for approximately 70 percent of NO3 capture. Also, despite the fact denitrification was stimulated in the filter strips, less N2O was emitted by the filter strips than from upland cropland. This suggests the greater amount of potentially mineralizable carbon in the filter strips supports a more complete conversion of NO3 to nitrogen gas. This work shows vegetative filter strips, when strategically located in agroecosystem watersheds, can reduce losses of nitrogen to the environment from cropping systems.

Corn stover harvest and reduced nutrient concentrations. Proponents of cellulosic biofuel need to understand how soil nutrient levels will be affected by removing corn stover for use as feedstock for cellulosic biofuel. More than 500 site-years of corn plant samples were collected by ARS scientists in Ames, Iowa, who divided plant samples into different parts (stems, leaves, and grain). All samples were analyzed to determine nutrient concentrations. The results showed that compared to harvesting only the grain, harvesting corn stover increased nitrogen, phosphorus, and potassium loss by 14, 1.4, and 16 pounds per ton, respectively. The losses of nitrogen and phosphorus are not considered enough to change current nitrogen and phosphorus fertilization practices for stover harvest rates of one ton/acre. However, the potassium loss is sufficiently high to warrant routine soil testing and plant analysis to monitor available potassium levels. This information provides guidelines for the acquisition of sufficient feedstock supplies to operate emerging cellulosic biofuel investments in a sustainable manner.

Cytokines as an alternative to antibiotics. Cytokines are small proteins that are important in cell signaling and that affect the behavior of other cells. The use of cytokines to stimulate the immune system as alternatives to antibiotics is a promising area of study. ARS scientists in Ames, Iowa, investigated the value of using the granulocyte colony stimulating factor (G-CSF) as an alternative to antibiotics in food animal production for controlling pathogenic bacteria in which neutrophils (white blood cells that are the first line of defense against bacterial infections)

can provide protection. G-CSF enhances the production and release of neutrophils from bone marrow and is already licensed for use in humans. The scientists found the administration of recombinant G-CSF induced a transient increase in neutrophils (neutrophilia) in pigs. However, delivery of porcine G-CSF inserted in a replication defective adenovirus (Ad5) vector significantly increased the effect of neutrophilia. Pigs given one injection of the Ad5-G-CSF had a neutrophilia that peaked between 3 to 11 days post-treatment, and neutrophil counts remained elevated for more than two weeks. Neutrophils from the treated pigs were fully functional based on laboratory tests, demonstrating G-CSF may be an effective alternative to antibiotics for treating bacterial pathogens susceptible to neutrophils.

Cooperating University: Mississippi State University

ARS Program, Joint Appointments and Facilities

Faculty in the Division of Agriculture, Forestry, and Veterinary Medicine at Mississippi State University are engaged in a unique collaboration with a myriad of scientists from the southeast area of the USDA-ARS. More than 20 research faculty associated with the Mississippi Agricultural and Forestry Experiment Station (MAFES) and the College of Veterinary Medicine collaborate with scientists from eight ARS research units on 24 different projects throughout the state. MSU and ARS scientists are co-located and share office and research facilities across the state. The MSU Delta Research and Extension Center (DREC) at Stoneville, Mississippi, serves as the central hub of this partnership, hosting the USDA-ARS Southeast Region Area Office.

Genomics and Bioinformatics

The Institute for Genomics, Biocomputing & Biotechnology (IGBB) at MSU works closely with the Genomics & Bioinformatics Research Unit (GBRU) in Stoneville, Mississippi. This partnership focuses on understanding the macromolecular interactions underlying agronomic and adaptive traits of crop plants (including cotton and rice) and their wild relatives. The IGBB/GBRU collaboration also involves study of the genomes of plant pests and pathogens (e.g., Palmer amaranth, boll weevil, reniform nematode, etc.) and the molecular mechanisms these species utilize to circumvent control strategies. One of the notable outcomes of this partnership was the sequencing of the cotton genome. IGBB staff are co-located at the GBRU to work on GBRU/IGBB research projects and advance computational biology infrastructure/capabilities in parallel and jointly.

Catfish Research and Diagnostics

Catfish is the largest aquaculture industry in the United States and more than 70 percent of the domestic production of catfish occurs in Mississippi. The Thad Cochran National Warmwater Aquaculture Center (TCNWAC), located at DREC in Stoneville, supports the catfish industry by providing research, diagnostic and outreach services. TCNWAC facilities include 283 ponds ranging in size from 0.1 – 9 acres, raceways, aquaria, and offices where ARS scientists associated with the USDA Warmwater Research Unit are co-located. TCNWAC hosts the Southern Regional Aquaculture Center and the CVM Catfish Diagnostic Lab. Over the last three decades, this multi-institutional collaboration has supported the industry with key advances in catfish nutrition, production practices, water quality, disease diagnostics and management, and

economics, thereby enhancing industry production, profitability, and sustainability. The synergism created by this partnership is illustrated in the development and commercialization of the ESC vaccine. This collaboration between MAFES-NWAC, MSU-Ag & Biological Engineering, and USDA/ARS/NBCL, has led to development of a validated oral vaccination platform that protects catfish against ESC. To date the vaccine has been shown to increase revenue in both channel and hybrid catfish ranging between $2,500-$3,500/acre.

Mississippi Alluvial Water Research Center
The Lower Mississippi River Basin is one of the most productive and intensively irrigated agricultural regions in the nation. Over 90 percent of irrigation water is pumped from the Mississippi River Valley Alluvial Aquifer, a shallow, highly productive aquifer underlying much of the region. Availability of water at relatively low cost has led to overuse of this aquifer and declining groundwater levels, negatively affecting base flows of streams, water quality, and aquatic and riparian habitat. MAFES has worked in cooperation with USDA-ARS to create a world class center of excellence in agricultural water management. To solve regional water problems, USDA-ARS and university scientists are working with collaborators, stakeholders, and customers to conduct comprehensive, regional, multi-institutional, and multidisciplinary research at scales ranging from fields to watersheds. This new Delta Water Center is housed on the campus of DREC where six ARS scientists and three MSU faculty share offices, labs, plot space, and equipment. This research is providing science-based concepts and knowledge on the effects of various water management practices on hydrologic processes, water conservation, water quality, ecology, and farm profitability.

ARS has 63 scientists located at Stoneville, Mississippi, who are associated with Mississippi State University's Delta Branch Experiment Station. These ARS scientists conduct research on insect management, crop genetics, cotton ginning, warm water aquaculture, biocontrol of pests, genomics and bioinformatics, and crop productions. The ARS scientists hold 19 university adjunct appointments and ten scientists serve in other appointed cooperative roles. The ARS scientists are located in ARS buildings adjacent to university buildings. ARS and university scientists share university facilities such as land and ponds used for research.

Selected ARS Accomplishments

New cotton germplasm resistant to cotton leaf curl virus. Although cotton leaf curl virus disease has not yet been reported in the United States, the USDA has ranked it among the top 20 potential threats to U.S. agriculture. USDA and other U.S. government agencies funded a multinational project to develop resistant cotton varieties, not for immediate cultivation, but to be prepared before the disease reaches the United States. Cotton germplasm was screened in Pakistan by in-country university cooperators for resistance to cotton leaf curl virus in Pakistan, where the disease is endemic and causes losses of a million bales of cotton each year. Breeding lines with potential resistance were identified for further breeding by an ARS scientist in Stoneville, Mississippi, who developed cotton lines with resistance to cotton leaf curl virus. This work allowed the scientist to identify two resistant germplasm lines of cotton, which have been made available to breeders for developing cotton leaf curl virus-resistant varieties.

Herbicide rotations and herbicide resistance in agricultural weeds. Weeds are evolving to become more herbicide-resistant, a trend that is threatening crop production and raising food costs. An analysis by ARS researchers of over 500 site-years of empirical data provided compelling evidence that herbicide rotation management—a strategy that is commonly recommended to growers to delay or prevent herbicide resistance—is not only ineffective but may actually exacerbate the problem. In contrast, this work highlights the importance of using single applications of chemically complex herbicides as a short-term method to forestall herbicide resistance while highly diversified weed management practices are established for long-term sustainable management. This finding provides new information that can be used by producers and custom applicators in designing the chemical control component of weed management programs.

Reducing ginning costs by improving ginning efficiency. Cotton cultivars differ in how strongly fibers are attached to the seed, and cultivars with less fiber-seed attachment force can be ginned faster with less energy and fiber damage. ARS cotton breeders and engineers in Stoneville, Mississippi, determined fuzz percentage was correlated with ginning efficiency, and selecting for genotypes with low fuzz percentage resulted in genotypes with better ginning efficiency. This finding will help cotton breeders develop cotton cultivars that gin faster with lower ginning energy requirements and high fiber quality.

Changes in catfish diets and feeding regimes. Companies that supply feeds to catfish producers remain competitive by identifying less expensive feed ingredients that do not negatively impact yields or product quality. ARS scientists in Stoneville, Mississippi, in cooperation with scientists at Mississippi State University, raised catfish on diets in which soybean meal was partially replaced with cottonseed meal, corn gluten, or corn germ, which are less expensive protein alternatives. The scientists determined that approximately half the soybean meal could be replaced with these alternatives without negatively affecting meat yield or meat quality. This finding provides feed manufacturers with an alternative feed composition that could effectively lower feed costs.

Cooperating University: North Carolina State University

ARS Program, Joint Appointments and Facilities

ARS has 18 scientists located at Raleigh, North Carolina, who are associated with North Carolina State University. ARS research at this location includes plant science, soybean and nitrogen fixation, food science, and market quality and handling. ARS scientists are located in both university and ARS facilities with some students and postdoctoral positions housed in ARS facilities. ARS scientists hold 19 adjunct appointments and serve in 19 advisory positions with the university.

Selected ARS Accomplishments

High-yielding drought-tolerant soybean cultivars. The cultivars are made possible by research conducted to broaden the narrow genetic base of U.S. soybean breeding by genetically tapping

into the treasure trove of genetic resources of the USDA soybean germplasm collection. Research harnesses genetic diversity in the USDA collection to develop new germplasm that has superior agronomic performance and has produced a cultivar with greater ability to withstand drought and other environmental stresses.

Spoilage of acidified vegetables by Bacillus. Research studies did not show the significance of Bacillus spoilage of acidified vegetables is a significant problem for industry, especially tomato processors. Yet in 2010, the FDA proposed guidance for the food industry stipulating that spores of Bacillus species needed to be killed by heat processing for the production of acidified vegetable products. Implementing the guidance would have been a significant burden to industry because the times and temperatures needed to thermally process these products would negatively affect product texture and quality. ARS scientists in Raleigh, North Carolina, undertook research to show how the different acids present in tomato vs. acidified vegetables (such as cucumber pickles, and peppers) affect the spoilage process. The acids added to preserve acidified vegetables (primarily vinegar) are sufficient to prevent Bacillus spoilage, whereas the malic acid naturally present in tomato products is not necessarily sufficient to prevent spoilage. These data were made available to the FDA and industry representatives for the development and implementation of science-based regulations and production practices.

Peanut butter improved by using encapsulated peanut skins. Healthier, better flavored peanut butter can be produced by using encapsulated peanut skins. Peanut processing plants, during the blanching operation, produce thousands of tons of peanut skins, which become a waste management problem for processors, who asked ARS for a solution. Peanut skins are known to contain high levels of polyphenolic compounds, which are healthy antioxidants, but also are bitter tasting. ARS scientists in Raleigh, North Carolina, extracted peanut skin polyphenolics and encapsulated them with food-grade maltodextrin, a sugar compound. These encapsulated peanut skins can be used to increase antioxidant bioactivity of other foods such as chocolate and peanut butter without adding a bitter flavor. ARS has initiated the patenting process for this technology and is pursuing the licensing of the technology with a pharmaceutical company.

Cooperating University: Oregon State University

ARS Program and Joint Appointments

ARS has 32 scientists report to its Corvallis, Oregon, location and most of the research is in association with Oregon State University. These ARS scientists conduct research on forage seed, cereals, and horticultural crops. ARS scientists also manage the National Clonal Germplasm Repository. The ARS scientists hold 26 university adjunct appointments or other types of cooperative appointments. These 26 scientists are in ARS facilities on the university campus that also houses 17 graduate students and where 32 undergraduate students assist with research. Two ARS personnel reporting to the Corvallis location are located in Washington State University facilities and four ARS personnel are co-located at the University of Idaho.

Selected ARS Accomplishments

"Clean" berry crops free of targeted pathogens. To be competitive and profitable, berry producers require clean plants (i.e., those with no viruses) that establish quickly and have higher yields and fruit quality than diseased plants. ARS scientists in Corvallis, Oregon, with collaborators at the university evaluated strawberry, blackberry, raspberry, elderberry, grape, and blueberry, eliminated viruses from multiple cultivars, and advanced selections as part of the National Clean Plant Network with funding from USDA-APHIS. These resulting "clean" plants are the starting material for certification programs that monitor and regulate the large-scale production of these crops. The testing and cleanup that occurred through this effort also is facilitating the export of more than 50 million berry plants for planting in other countries.

Land use practices and stream and river water quality. Assessing how land use alters water quality of nearby streams and rivers is an important aspect of pollution monitoring and natural resource stewardship. Tools are needed that can quantify how land use alters stream and river water quality over long time periods. ARS scientists in Corvallis, Oregon, collected data over an eight-year period to define 56 land use patterns of crops, forests, and urban development that represented 99 percent of the Willamette River Basin of western Oregon. The data collected were incorporated into the Soil and Water Assessment Tool model. In validation tests, the model showed an increased capability to predict how land management altered nutrient and sediment load in streams and rivers. Researchers now will be able to determine the environmental consequences of changing land use patterns.

New farm-scale gasifier unit for creating value-added products. Finding new uses for agricultural byproducts can help increase the economic resilience of individual farms. ARS scientists in Corvallis, Oregon, worked with a private non-profit group to develop and test a farm-scale gasification unit that can convert residues from seed cleaning into value-added products. This public-private collaboration demonstrated the unit could convert over 400 pounds of feedstock per hour into syngas and organic carbon-rich biochar that could improve the organic content of acidic soils in eastern Washington State. This work led to the formation of a company that will make the technology available to farmers and other owners of seed cleaning mills.

Cooperating University: Purdue University

ARS Program and Joint Appointments

ARS has 21 scientists located at West Lafayette, Indiana, who are associated with Purdue University. These ARS scientists conduct research on crop production and pest control, soil erosion and livestock behavior. The ARS scientists hold 15 university adjunct appointments and 14 of those scientists hold other cooperative appointments. Two of the three ARS research units are located in university buildings and the other unit is in a federal building on the university campus.

Selected ARS Accomplishments

Enhancing nutrition of soybean meal. Meal produced from soybeans comprises a major source of protein for animal production in the United States. Soybean seeds contain low levels of the complex oligosaccharides raffinose and stachyose, which cause discomfort to monogastric animals and slow weight gain. Eliminating these compounds improves animal health and growth rate. Only limited genetic variation exists for this carbohydrate composition trait in the available soybean germplasm. By specifically targeting genes based on understanding of carbohydrate biosynthesis, soybean lines carrying mutations in key genes in this pathway with the potential to eliminate these anti-nutritional compounds have been provided to breeders. The research project spans gene discovery to the development of cultivars with improved meal quality and the evaluation of this meal in chicken feeding trials. Other cooperating universities include University of Missouri, University of Minnesota, and University of Arkansas.

Mitigating phosphorus loss ensures safe drinking water. The midwestern United States has some of the most productive agricultural soils in the world, but because of its climate much of this region would be unable to support agriculture without drainage. High water tables would both damage crops and prevent the access of machinery in the fields at critical times. While drainage is designed to remove excess water as quickly as possible, it also can provide a conduit for the rapid loss of agrochemicals, particularly phosphorus, which can subsequently degrade the quality of key drinking water supplies. ARS scientists in West Lafayette, Indiana, used a combination of field and modeling investigations to provide information on how to mitigate phosphorus losses from tile-drained croplands in conservation tillage. As researchers, policymakers, and farmers search for ways to reduce phosphorus loadings to surface waters such as Lake Erie, these studies highlight the importance of treating both surface runoff and tile drainage to minimize harmful algal blooms.

Tear staining in pigs as an indication of stress. Non-invasive indicators of welfare are needed to aid with on-farm welfare assessment. Having previously determined that tear staining amounts were related to stress measures, ARS researchers in West Lafayette, Indiana, and collaborators at the University of Helsinki, Finland, investigated tear staining in pigs housed on farms with different amounts of tail-biting damage and access to different environmental enrichments. Pigs with greater tail damage scores had higher tear staining scores and tear staining was reduced in pigs with access to multiple environmental enrichment objects. Further validation of this measure will enable producers and auditors to identify pigs with elevated stress levels at the pen and individual animal level and carry out timely interventions to improve animal welfare.

Cooperating Universities: Texas Tech University and Texas A&M University

ARS Program, Joint Appointments and Facilities

ARS has 21 scientists located at or near Lubbock, Texas, who are associated with the Cropping Systems Research Laboratory. They conduct research on plant stress and germplasm development, wind erosion and water conservation, cotton production and processing, and livestock issues. The ARS scientists hold 27 adjunct appointments at two different universities

and 17 other types of university appointments where some teach, guide graduate students, supervise post-doctoral scientists, and share grants. In addition, there are 11 joint appointments between Texas Tech and Texas A&M AgriLife Research and Extension where salaries are cost-shared. Eighteen of the ARS scientists are located in a federal building adjacent to the Texas Tech campus and three scientists are located in the Texas A&M AgriLife Research and Extension Center at Lubbock.

Selected ARS Accomplishments

Transition to alternative cropping systems to require less water. The Texas High Plains is in the midst of a transition of cropping systems that rely less on irrigation from a diminishing water supply to more dryland production. Scientists using a systems approach are working towards providing practical and novel solutions on how to maximize returns for irrigation-water pumped from the Ogallala Aquifer and received from rainfall. Conserved water is delivered to farmers using solutions and tools derived from basic and practical research conducted by a multidisciplinary team of scientists. These solutions include tools to detect and monitor water and thermal stresses, germplasm to cope with these stresses using traditional breeding and molecular approaches, and cropping systems management using state-of-the art simulation models. The long-term objective is the preservation of natural resources, soil and water, to maximize economic returns, and provide economic stability to the region.

Ogallala Aquifer Program and the water supply. ARS works to improve water conservation for the Ogallala Aquifer with a consortium of universities in Kansas and Texas to help agricultural producers use this resource as cost-effectively as possible. The Ogallala Aquifer covers around 225,000 square miles in eight states from South Dakota to Texas and supplies 30 percent of all groundwater used for irrigation. But increasing demands from agricultural, municipal, and industrial development on the Great Plains has led to water being pumped out of a large portion of the aquifer much more quickly than can be replenished. By helping producers determine how to maximize returns for each acre-foot of water used, the Ogallala Aquifer Program helps conserve this irreplaceable natural resource. It also helps to preserve the agricultural community that depends on the Ogallala Aquifer as a catalyst for economic activity, since every dollar of farm income has a substantial multiplier effect in the rural community. The ARS scientists at Lubbock participate in a program led by ARS scientists in Bushland that includes Texas A&M AgriLife Research, Texas Tech University, Kansas State University and Southwest Texas A&M University.

Increased seed numbers in sorghum. Seed number per panicle (head) is a major determinant of grain yield in sorghum and other cereal crops and increasing seed numbers is an efficient way of increasing production and profitability for farmers without increasing acreage farmed. From the sorghum experimental lines maintained at their location, ARS researchers in Lubbock, Texas, isolated several multi-seeded mutants with potential to double seed numbers and significantly enhance the seed weight per panicle in sorghum. In collaboration with ARS researchers in Ithaca, New York, the scientists then identified four genes underlying the multi-seeded trait through next-generation sequencing. The lines with multi-seed traits have been distributed to researchers and seed companies for the development of high yield sorghum hybrids.

Yeast supplementation and the well-being of stressed calves. Livestock management practices do not always provide optimal protection from disease. One of the most stressful times in the life cycle of a calf is removal from its mother and shipment to a feedlot where it mingles with other unfamiliar calves, and the resulting stress increases the incidence of disease. Identification of feed supplements to ensure health, growth, and overall well-being is of benefit to livestock producers. ARS scientists in Lubbock, Texas, with colleagues at the University of Nebraska, determined feeding a yeast supplement to calves that fail to grow or develop normally as a consequence of disease improved both the calves' health and growth. Yeast may prove to be a beneficial, antibiotic-free supplement for the livestock industry to manage calves with the highest risk for becoming ill.

Cooperating University: University of Wisconsin

ARS Program, Joint Appointments and Facilities

ARS has 40 scientists located at Madison, Wisconsin, who are associated with University of Wisconsin. ARS scientists conduct research on cell wall biology and utilization, vegetable crops, cereal diseases, dairy forages and aquaculture. ARS scientists hold 21 university adjunct appointments and 11 scientists serve in other appointed cooperative roles. ARS scientists are located in ARS buildings on the university campus and in university buildings.

Selected ARS Accomplishments

High quality, cold-tolerant, grass variety and improved grazing systems. Livestock producers who use management-intensive grazing systems need improved high-quality and long-lived forage grass varieties that support cattle growth and milk production. ARS scientists in Madison, Wisconsin, developed and released Hidden Valley meadow fescue to the public. Because of its increased fiber digestibility, this grass variety represents a significant improvement in forage quality over other pasture forage varieties. It also has a higher tolerance for cold temperatures and is better adapted for humid temperate regions of the eastern United States and Canada. In response to company requests, seed was produced and distributed for further seed multiplication and commercialization. Hidden Valley meadow fescue is expected to fill a significant demand for a cold-tolerant, drought-tolerant, and high-quality grass for intensive grazing systems in the north central and northeastern United States, which will help improve livestock health and producer profits.

Reducing phosphorus loss on dairy farms. Surveys, in combination with new advanced models, can reliably and quickly determine areas that need attention in order to reduce phosphorus loss on dairy farms. Loss of phosphorus from runoff on dairy farms can pollute local waters; it is difficult to identify the areas on a particular site that are most responsible for these losses. ARS scientists in Madison, Wisconsin, monitored phosphorus runoff from cattle pastures and extensively surveyed four pasture-based dairy farms over a multi-year period. Data on runoff and farm management were combined with topographical information to develop advanced computer models to quantify phosphorus loss from a particular site. The research demonstrated surveys

such as this, in combination with new advanced models, can reliably and quickly determine areas that need attention.

Potato clones resistant to both late blight and early blight. U.S. potato production, currently valued at more than $4 billion a year, as well as potato production internationally, continually are threatened by the devastating potato early and late blight diseases, requiring many fungicide applications every year. The development of potato varieties with resistance to both diseases would reduce the environmental impacts of fungicide application, improve profitability for growers, and is currently not available in commercial potato cultivars. ARS scientists in Madison, Wisconsin, have evaluated potato germplasm to determine the genetic basis of disease resistance. That information enabled them to identify key resistance genes and incorporate them into three potato clones with resistance to both diseases.

Cooperating Universities: Baylor University and Tufts University

Program, Joint Appointments, and Facilities

ARS research on human nutrition is conducted primarily at six centers: Arkansas Children's Nutrition Center at University of Arkansas for Medical Sciences (maternal/child nutrition and impacts of physical activity); Beltsville Human Nutrition Research Center (absorption, metabolism, bioactive food impacts, dietary regulation of immunity and inflammation, health promoting roles of foods); USDA/ARS Children's Nutrition Research Center, Baylor College of Medicine (molecular, cellular aspects of nutrition during human development, childhood obesity); Grand Forks Human Nutrition Research Center (biology of obesity prevention, food factors to prevent obesity and related diseases); Jean Mayer Human Nutrition Research Center on Aging affiliated with Tufts University (cancer prevention via diet, cardiovascular nutrition and health, energy regulation and obesity); and the Western Human Nutrition Research Center at the University of California, Davis (define nutrition interventions that promote good health). Several of these locations are an integral part of research at their affiliated universities. ARS is somewhat unique in that it is working with private universities, and because of that uniqueness, research at two of those universities was selected to be highlighted: Children's Nutrition Research Center at Baylor College of Medicine, Houston, Texas; and the Jean Mayer Human Nutrition Research Center on Aging, at Tufts University, Boston, Massachusetts.

The research at these centers is conducted primarily by university scientists, with many working in ARS buildings adjacent to the university campuses. ARS has 17 employees at the Houston location and five employees at the Boston location, to assist in coordinating research at those locations with other ARS research.

Selected Accomplishments

Parenting practices and improved vegetable consumption by toddlers. Dietary habits often are established early in life. Since Americans of all ages eat less than half the recommended servings of vegetables, ARS-supported scientists in Houston, Texas, surveyed more than 300 mothers of pre-school children about their attitudes, habits, and emotions regarding children's nutritional

needs and about actual vegetable consumption by their pre-school children. The researchers determined half the variation in children's vegetable consumption could be explained by three factors, in decreasing order of importance: (1) actively involving the child in choosing vegetables in the store, (2) praising the child for eating vegetables, and (3) automatically including vegetables on the plate. This was the first study to test a behavioral model to predict effective parenting practices that increase vegetable consumption and should lead to designing successful interventions.

Rice consumption and better adult nutrition. Rice consumption has doubled in the United States over the last 20 years and enriched, fortified white rice makes up more than 70 percent of that increase. ARS-funded researchers in Houston, Texas, used data from the National Health and Nutrition Examination Survey (NHANES 2005-2010) to assess the association of adult rice intake with nutrient intake and diet quality. Rice consumption was associated with consistently better diet quality and nutrient intake, including better intakes of dietary fiber, folate, magnesium, iron and potassium, and greater consumption of fruit, dark green/orange vegetables, grains, meat/beans, and oils. These results show including rice in the diet complements a pattern of healthy eating.

Absorption of vitamin D when taken with a meal. An issue that complicates the process of correcting vitamin D deficiency is individual responses to a given dose of the vitamin vary widely. ARS-funded researchers in Boston, Massachusetts, had previously found supplemental vitamin D is absorbed more efficiently when the supplement is taken with a meal. They conducted a follow-up study of 50 healthy older adults to determine whether the presence of fat in the meal influenced vitamin D absorption. Their results indicate absorption of vitamin D from a supplement was over 30 percent greater when the supplement was taken with a meal containing fat (in an amount commonly consumed) than with a fat-free meal. This research may lead to more effective strategies for older adults to achieve and maintain healthy vitamin D levels that protect bone and cognitive health.

Fast-food restaurant menu items impact on chronic disease. Consumption of foods with higher levels of energy, sodium, saturated fat, and trans fat are associated with an increased risk of chronic disease. Trends in fast-food restaurant portion sizes may have an impact. ARS-funded researchers in Boston, Massachusetts, examined the variability of portion sizes in popular food items in three U.S. fast-food restaurants. Their study included tracking changes in portion size and the levels of energy, sodium, saturated fat, and trans fat in french fries, cheeseburgers, grilled chicken sandwiches, and regular cola. Overall, 56 percent of items decreased in energy content from 1996-2013, while energy content increased in 44 percent of the items. At the same time, sodium levels in 18 percent of the items decreased significantly, while sodium levels in 33 percent of the items were higher, but the absolute differences were modest. In 2013, the energy content of a large-sized "meal" (cheeseburger, french fries, and regular cola) represented 65 to 80 percent of a 2,000-calorie-per-day diet, as well as a significant portion of recommended sodium intake. These findings suggest efforts to promote reductions in energy, sodium, saturated fat, and trans fat intakes need to be shifted from emphasizing portion size to emphasizing total calories, frequency of eating, number of items ordered, menu choices, and energy-containing beverages.

Understanding normal biological pathways and reducing cataracts. The human eye lens requires soluble proteins to establish and maintain a clear lens, and cataracts develop as the eye lens loses its ability to eliminate insoluble proteins that develop from stresses and aging. ARS-funded researchers in Boston, Massachusetts, discovered pathways by which lens proteins are kept soluble and/or are recognized for degradation and elimination. The findings are essential for understanding how nutritional interventions into natural systems have the potential to help preserve vision and diminish the burden from cataracts, which afflicts 17,000,000 people worldwide.

Blood levels of zinc in the aging. Two studies concerning zinc blood levels performed at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University in Massachusetts have led to guidance on zinc influence on health. Those individuals who are aging or age can have less than optimal amounts of zinc in their blood. In one study it was found that patients with normal blood zinc levels were 50 percent less likely to develop pneumonia, and therefore it was important to ensure those levels are normal. Diet and supplements can be used to aid in that effort. Another study found raising zinc levels to what is considered normal contributed to increased T cells. T cells play a key role in immune responses.

Long-term, Multiple-location Initiatives

ARS is addressing the complex issue of multiple land use without compromising soil health, water, or air resources. Meeting these needs requires sustained long-term research (10 or more years) on management practices across the varied U.S. landscape. ARS is in a unique position to conduct and coordinate such research, which usually involves universities and may involve other government agencies as well as representatives from the private sector. Three examples of long-term national initiatives are provided.

Long-Term Agroecosystem Research

The Long-Term Agroecosystem Research (LTAR) network enables long-term, trans-disciplinary science across farm resource regions to address these challenges. The goal of this research network is to ensure sustained crop and livestock production and ecosystem services from agroecosystems, and to forecast and verify the effects of environmental trends, public policies, and emerging technologies. This Shared Research Strategy (SRS) is a living document, founded on the basic goals of the LTAR network and designed to capitalize on the strengths of the 18 LTAR sites. The LTAR SRS creates common geographically and temporally scalable databases that deliver knowledge and applications within the following four priority areas of concern: (1) agroecosystem productivity and sustainability; (2) climate variability and change; (3) conservation and environmental quality; and 4) socioeconomic viability and opportunities.

A key expectation of the LTAR network is the application of research results to solve critical challenges facing agriculture. Because research-based applications and their outcomes are impacted by continually changing trends, demands, and innovations, the LTAR SRS exploits a mixture of data from ongoing networked science, new cross-site experiments, and long-term historical measurements.

About 60 U.S. universities, 15 U.S. federal government agencies, 30 international collaborations, 10 network collaborations, 20 non-government organizations, and 12 state government agencies are associated with this initiative led by ARS.

Resilient Economic Agricultural Practices

Resilient Economic Agricultural Practices (REAP) is a sustained, long-term research project on land management practices across the varied U.S. landscape. Multiple-year assessment is necessary to demonstrate consistently detectable soil health changes in response to land management decisions. Currently, six years of research has been accumulated by scientists from ARS and their land-grant university partners at locations in 13 states. ARS and the Department of Energy provided major funding at the beginning. At the request of ARS, the DOE support at was replaced primarily with private funds through the ATIP Foundation. This means uninterrupted continuation of this important research to sustain data development, collection and development of guidelines and tools needed to assess long-term effects of food, animal feed, fiber, and biofuels production on soil health.

Land-grant universities in the 13 states are cooperating with the effort along with a number of companies that are providing funds through ATIP.

Agricultural Carbon Enhancement

The Agricultural Carbon Enhancement project is a research program initiated in the early 2000s. The project involves a network of over 45 ARS and university researchers collecting and sharing data from over 30 locations in more than 20 states. Goals are to better quantify greenhouse gas (GHG) emissions from cropped and grazed soils under current management practices, and to identify and further develop improved management practices that will enhance carbon (C) sequestration in soils, decrease GHG emissions, promote sustainability and provide a sound scientific basis for carbon credits and GHG trading programs. This program generates information that is needed by agro-ecosystem modelers, producers, program managers and policy makers. Coordinated multi-location field studies follow standardized protocols to compare net GHG emissions (carbon dioxide, nitrous oxide, methane), C sequestration, crop/forage yields, and broad environmental benefits under different management systems that typify existing production practices, maximize C sequestration, minimize net GHG emissions and meet sustainable production and broad environmental benefit goals

The application Geospatial Portal for Scientific Research (GPSR) is an ongoing effort of the ARS to increase the availability of research data to the broader research community. The data contained within this application represents complex data relationships amongst hundreds of scientific measurements.

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