FY2020 ANNUAL TECHNOLOGY TRANSFER REPORT

USDA

MAY 2021

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INTRODUCTION

President Abraham Lincoln coined the phrase "the People's Department," acknowledging the role of the U.S. Department of Agriculture in solving problems–a service that benefits all people every day. Thus, well before the coining of the modern-day phrase of "technology transfer," it was the culture of USDA to deliver solutions to the people of the United States. Today, USDA broadly defines technology transfer as the adoption of research outcomes (i.e., solutions) for public benefit. 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 (CRADA) 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). Additionally, successful adoption of USDA knowledge and research outcomes typically requires 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 arenas.

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 (PPPs), 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. agriculture sector. Thus, technology-transfer functions are critical to accelerating utility of public research and development investments, creating economic activity, and in job creation and sustainable economic development.

The USDA, Agricultural Research Service (ARS) has been delegated authority by the U.S. Secretary of Agriculture to administer the patent program for ARS and to review CRADAs and administer technology licensing programs for all intramural research conducted by USDA. These activities are housed in the Office of Technology Transfer.

On October 28, 2011, following a series of reports identifying the status of technology transfer from Federal funds and Federal laboratories, the White House issued the Presidential Memorandum – "Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses." Issuance of this Memorandum provided an unprecedented opportunity for unifying technology transfer across USDA science and technology agencies as the mechanism to deliver these outcomes for public good. In the USDA's response to the Presidential Memorandum (http://www.nist.gov/tpo/publications/upload/USDA-Tech-Transfer-Plan.pdf), several initiatives were identified to promote technology transfer and commercialization. These initiatives ushered in a new era of unprecedented collaboration among USDA agencies to enhance services and opportunities to the

customers and stakeholders of the Department. This report describes progress in implementing these initiatives.

This report also covers technology-transfer activities and metrics for the USDA, Agricultural Marketing Service (AMS), Animal and Plant Health Inspection Service (APHIS), Agricultural Research Service (ARS), Economic Research Service (ERS), Foreign Agricultural Service (FAS), Food Safety and Inspection Service (FSIS), Forest Service (FS), National Agricultural Statistics Service (NASS), National Institute of Food and Agriculture (NIFA), Natural Resources Conservation Service (NRCS), and Rural Development (RD).

COMBINED METRIC TABLES FOR ALL USDA AGENCIES

Table 1. Invention disclosures and patenting profile from Animal and Plant Health Inspection Service, Agricultural Research Service, and Forest Service. ND = no data.

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Invention Disclosures					
New inventions disclosed	202	193	320	243	213
Patents					
Patent applications filed	109	125	115	97	91
Patents issued	62	74	67	71	58
Foreign Patenting					
Foreign patent applications filed	ND	ND	ND	ND	61
PCT Applications Filed	ND	ND	ND	ND	16
Foreign patents issued	ND	ND	ND	ND	5

Table 2. Licensing profile from Animal and Plant Health Inspection Service, Agricultural Research Service (ARS), and Forest Service (FS). Most of the licensing income came from ARS. NP = data not presented due to confidentiality.

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Total Active Licenses	441	438	473	512	582
New Licenses	33	38	41	51	93
Total Earned Royalty Income (ERI)	$3,638,276	$3,503,891	$2,716,369	$3,171,495	$2,678,183
Median ERI[2]	$3,966	$3,698	$3,056	$3,154	$4,221
Minimum ERI[2]	$5	$15	$21	$ 0.75	$13
Maximum ERI[2]	$818,537	$769,167	$265,844	$573,545	$279,915
ERI from top 1% of licenses[2]	NP	NP	NP	NP	NP
ERI from top 5% of licenses[2]	$1,811,637	$1,639,557	$1,218,975	$1,579,185	$1,111,917
ERI from top 20% of licenses[2]	$3,043,395	$2,933,342	$2,227,058	$2,655,368	$2,210,427
ERI distributed					
Percentage Distributed to Inventors	25	25	25	25	25
Percentage Distributed to Lab/Agency	0	0	0	0	0
Innovation Fund[3]	ND	$483,814	$618,000	$833,500	$898,144
Licenses terminated for cause	0	0	0	0	0

[1]Only reported for ARS and FS.
[2]Only reported for ARS.
[3]Only used by ARS. Funds are from previous year's revenue.

Table 3. Cooperative Research and Development Agreements (CRADA), Material Transfer Research Agreements (MTRAs), and other research collaborations. CRADA are from Agricultural Research Service, Animal and Plant Health Inspection Service, Forest Service, and Agricultural Marketing Service. Most of the CRADA and MTRA numbers are from Agricultural Research Service.

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
CRADAs					
Active CRADAs	301	329	218	260	221
Newly Executed CRADAs	74	91	61	95	84
Active CRADAs with small businesses	70	62	73	120	64
New CRADAs with small businesses	14	17	32	41	21
MTRAs					
Active MTRAs	295	443	369	305	336
Newly executed MTRAs	96	112	133	113	119
Other Collaborative Research Agreement[1]					
Active other collaborative research agreements	3,230	4,108	3,215	1,888	1,987
New other collaborative research agreements	756	876	621	951	1,210

[1] Trust Fund Cooperative Agreements, Reimbursable Agreements, Specific Cooperative Agreements and Non-Funded Cooperative Agreements, Cooperative Agreements, Inter-agency & Intra-agency Agreements.

1.0. Agricultural Marketing Service (AMS)

1.1. Mission Statement

The mission of the Agricultural Marketing Service (AMS) is to facilitate the strategic marketing of agricultural products in domestic and international markets, while ensuring fair trading practices and promoting a competitive and efficient marketplace to the benefit of producers, traders, and consumers of U.S. food and fiber products. AMS carries out a wide range of programs under the authorization of the Agricultural Marketing Act of 1946 as well as over 50 other statutes. More than half of the funds needed to finance AMS activities (excluding commodity purchase program funds) are derived from voluntary user fees. AMS also provides services for private industry and State/Federal agencies on a reimbursable basis. In addition, AMS conducts several appropriated program activities through cooperative arrangements with State Departments of Agriculture and other agencies.

1.2. Nature and Structure of Program

Because of its producer-consumer focus, AMS's technology developments and transfer are directed to customer service and the customer-consumer interface. Licensing and technology transfer are handled through the separate business units and divisions within AMS. Still, the agency oversees several programs where innovative technological tools and practices have been used to assist agency stakeholders in marketing their food and fiber commodities. Communication of the agency's technology perspective highlights awareness of new technologies and facilitates improvement of existing

technologies used by AMS. For example, one context of technology transfer by AMS provides protocols and procedures for unifying food and commodity data from different sources into harmonized platforms permitting easy access to data for stakeholders.

1.3. Food Disclosure and Labeling Division

The Food Disclosure and Labeling Division (FDLD) administers the Country of Origin Labeling (COOL) program and the National Bioengineered Food Disclosure Standard (NBFDS). COOL requires retailers such as full-line grocery stores, supermarkets, and club warehouse stores to inform customers of the source of certain foods, including: muscle cut and ground lamb, goat, and chicken; wild and farm-raised fish and shellfish; fresh and frozen fruits and vegetables; peanuts, pecans, and macadamia nuts; and ginseng. COOL is enforced through retail store compliance reviews, supplier trace back audits, COOL supplier certification, remote retailer reviews, and consumer complaints. Starting January 1, 2022, the NBFDS requires a bioengineered food disclosure on foods that are or may be bioengineered.

In FY 2020, FDLD published guidance documents to help regulated entities validate a refining process and select a testing method for the NBFDS. These guidance documents will help industry determine whether their foods require bioengineered food disclosure. To help regulated entities understand the requirements of the NBFDS, FDLD staff continued with outreach and presented at conferences, reaching over 700 people. FDLD completed 58 supplier traceback audits, 3,343 initial retail reviews, 270 follow-up retail reviews, and responded to 14 consumer complaints.

In FY 2020, FDLD initiated its transition to a customer relationship management (CRM) system that will automate a number of tasks that are currently performed manually and streamline the division's operations. The system will serve as a repository for data collected through retail reviews, supplier traceback audits, and consumer complaints. The CRM system will also incorporate complaints received under the Standard after the mandatory compliance date of January 1, 2022. In addition, the CRM system will generate dashboards that will enable leadership to make strategic decisions and track progress toward objectives in its annual operating plan.

1.4. National Organic Program (NOP)

USDA oversees organic agricultural products through the AMS National Organic Program (NOP). The organic market continues to grow worldwide, providing new export and import opportunities for organic farms and businesses. Rapid organic growth has increased the complexity of supply chains that carry organic products from farm to table. AMS facilitates international trade for U.S. organic farms and businesses and makes sure USDA-certified organic products produced domestically and around the world comply with the organic standards.

Import and export systems are important tools for tracking products coming into and out of different countries. USDA is currently working with the U.S. Customs and Border Protection (CBP) agency to establish ways to better identify organic products coming into the United States using the Automated Commercial Environment (ACE) system. The ACE system facilitates the real-time collection, sharing and processing of import trade data with CBP.

AMS has taken actions to increase the transparency and availability of data for other countries involved in organic trade. The Organic Integrity Database has significantly increased the visibility of organic businesses, and directly advances our compliance and enforcement work. The new AMS organic export certificate system provides electronic certificates about organic shipments. This system can either be accessed by other governments or our data can feed into other countries' import systems. In early spring 2019, AMS launched an internal Compliance Database. The database helps to better track NOP's progress on complaint investigations and more quickly identify patterns and relationships across complaints.

Investment in organic systems directly advances AMS goals related to organic supply chain integrity, technology modernization, and customer service. USDA is currently considering foundational needs for a global organic oversight system. The ultimate goal is to develop technologies that would allow organic certifiers to approve transactions along an organic supply chain in real-time, enabling them to conduct mass balance checks and to detect fraudulent activity across the supply chain. A comprehensive system would allow government oversight bodies to audit across supply chains, fulfilling the goal of tracing products from farm to market and back. The system would create an inter-connected network, where data can be exchanged between different government oversight systems and existing corporate supply chain systems. Such technology investments are key to protecting organic integrity and facilitating access to international organic markets.

1.5. Market News Service

The AMS Market News service collects, analyzes, and disseminates current market information to assist producers and marketers of farm products and those in related industries in making critical daily decisions. Market News information covers local, regional, national, and international markets and includes data on supply, movement, contractual agreements, inventories, and prices for numerous agricultural commodities, both conventionally and organically produced. Reported commodities include cotton, cottonseed, and tobacco; dairy products; fruits, vegetables and ornamentals; livestock, meat, grains, poultry, and eggs. Market News has made great technological strides to improve access to market information through the development of Market Analysis and Reporting Services (MARS). MARS allows AMS to manage and publish Market News data in one centralized customer facing database, replacing multiple legacy systems. This new system reflects advances in data management, improves market transparency, reduces information disadvantages that may exist between buyers and sellers, and continues the Market News commitment to use experienced reporters to gather, analyze, and provide unbiased data through cooperative relationships and observation of different points within the agricultural supply chain. MARS makes Market News more flexible in a rapidly evolving digital market. It also makes quantifiable data available in a searchable database. In FY 2020, MARS and its public facing website, My Market News, continued to add more market types and reports to those available to the public. Through My Market News, users can access over 470 unique market reports disseminated from over 45 Market News offices across the country. Users can access all dairy, cotton quality, cotton forward contract, cotton organic, cotton yearly varieties, egg inventory, livestock auction, cold storage, specialty crop trends, and hay auction information through My Market News. Cotton, hay, rice, and livestock auction retail data, specialty crops shipping point, truck rates and terminal data, tobacco, video

auctions, grain, and feedstuffs information are in development, and data for those commodities are accessible to the public. Developers expect all voluntary Market News reporting data products to be collected and publicly disseminated through MARS over the next few years. Additionally, through the MARS Application Programming Interface (API), customers can now access data from over 450 unique market reports. The API allows users to automatically download data in custom formats. It is anticipated that basic development of MARS will be completed by FY 2021, reducing costs to annual system support and maintenance. Technology Accomplishments for AMS Market News include: completion of the MARS Welcome Packets for Trends, Terminals, Shipping Point, Truck Rates, and Movement; conducting trends testing in MARS and beginning the issuance of weekly trends report through MARS; final testing of a new Cornell upgraded site; opening of a new Cornell file repository; determining issues with the My Market News user interface and proposal of changes needed; AZURE migration; upgrade to VM Servers for: MNIS, MNCS, portal; resolution of issues with text reports not posting and data not moving to the portal by working with MNSB; revision of header statement for all Free on Board (FOB) reports and providing several reporters with access to ACE system with plans to transition northern border reporting data sources from Cognos to ACE ITDS.

1.6. Laboratory Approval and Testing Division

Through the Laboratory Approval and Testing Division, AMS provides lab testing and approval services to facilitate domestic and international marketing of food and agricultural commodities. The National Science Laboratories (NSL) provide analytical testing services for a fee. Analytical services include microbiological, chemical, physical, and bio-molecular analyses on a wide variety of food products and

agricultural commodities. NSL supports AMS commodity programs with analytical and scientific support for voluntary grading, commodity purchases, and export certification programs. NSL also serves other USDA and Federal Government agencies, commercial enterprises, academic and research institutions, and private individuals.

NSL provides technological benefits to the agricultural community and consumers via testing of a wide variety of products for diverse stakeholders. For example, NSL provides microbiological and nutritional testing of operational rations purchased by the U.S. military. In FY 2020, NSL had to overcome the challenges of COVID-19 pandemic—new health and safety measures, staff absences, changes in lab operations, stress and fear. In addition to these challenges, the COVID-19 pandemic increased consumer demand for peanuts, citrus juices, and honey. NSL continued to deliver timely service to customers on samples that exceeded the same time period in 2019 by 85 percent, 105 percent, and 484 percent for peanuts, juice, and honey, respectively. In FY 2020, amongst the COVID-19 pandemic, NSL continued to expand its testing capabilities for economic adulteration and authenticity in food and beverages, which provides critical information on quality and safety parameters for compliance of products such as citrus juice, honey, and olive oil. NSL added instrumentation and test methods and expanded service to new customers and types of juices.

Additionally, in FY 2020, NSL adopted three new testing technologies that will increase the efficiency and quality of the microbiological and chemical testing services. Also, NSL implemented over 10 process improvements in its efforts to automate processes and go electronic (i.e., reduce or eliminate paper).

NSL also routinely supports the vast missions of AMS by testing for quality and safety parameters of commodities procured for the USDA Foods Program, including the National School Lunch Program, pesticide residues in organic commodities for compliance to organic standards; and pesticide residues in specialty products for the Pesticide Data Program which helps to monitor pesticide residue levels in U.S. food.

The Laboratory Approval Service (LAS) approves or accredits, other laboratories to perform testing services in support of domestic and international trade. At the request of industry, other Federal agencies, or foreign governments, AMS develops and administers laboratory approval programs to verify that the analysis of food and agricultural products meet country or customer-specific requirements and is performed by qualified laboratories. In FY 2020, LAS launched its new mobile auditing application, Extensible Assessment Manager (ExAM). This is the first application being developed within AMS that allows audits/inspections to be conducted in a mobile environment. The application also tracks engagement with laboratories, digitizes the audit/inspection, testing and accreditation processes, standardizes workflows, enables robust automation of reporting, and enhances recordkeeping and data analytics. While developing ExAM, LAS made process improvements and changes to its current paper-based system in order to for customers and auditors to gain familiarity and consistency prior to transitioning to the new application.

Also, in FY 2020, due to the COVID-19 pandemic restrictions, to carry out its mission, LAS quickly customized auditing operations, using audio/visual applications to perform audits in a remote and virtual environment.

1.7. Monitoring Program Division

The Pesticide Data Program (PDP) is a national pesticide residue monitoring program and produces the most comprehensive pesticide residue database for food in the United States. Since 1991, PDP has tested 126 different commodities and 770 different pesticide residues. In FY 2020, PDP tested nearly 10,000 samples and generated over 2.5 million new data points. All data are available to the public electronically by way of the PDP website and customized reports are generated when requested. The Environmental Protection Agency uses the data to assess dietary risks from pesticide exposure and determine which pesticides can continue to be used in domestic agricultural production. It also uses the data to harmonize U.S. pesticide tolerance levels with international levels. The Food and Drug Administration uses the data to enhance its surveillance of imported foods. State public health and environmental agencies use the data to fulfill their consumer protection commitments. Growers and distributors use the data to resolve trade issues. PDP data has also been submitted to the Codex Alimentarius Committee to assist in benchmarking international Maximum Residue Levels (MRLs) as real-life data (in place of theoretical data), contributing to more accurate MRL estimates.

1.8. Plant Variety Protection Office

The Plant Variety Protection (PVP) Act provides legal and intellectual property rights protection to developers of new varieties of plants that are sexually propagated, asexually reproduced or tuber propagated. This voluntary program is funded through application fees for certificates of protection. Currently, more than 150 species of plants are protected under the PVP Act and more than 8,300

certificates of protection are in force. In FY 2020, the Plant Variety Protection Office (PVPO) received 445 applications of new seed, vegetative, and tuber propagated agricultural and ornamental plant varieties, conducted examinations on 500 applications to determine if plants were a new variety, and issued 599 certificates of protection. In FY 2020, in addition to carrying out its mission, PVPO published the revised PVP Regulations on January 6, 2020, to implement the 2018 Farm Bill amendment of the PVP Act. The amendment extends plant variety protection to asexually reproduced varieties of plants. PVPO started to offer plant variety protection for seed-propagated hemp, based on another Farm Bill change. PVPO also implemented the 5th release to update its electronic application system to allow bulk upload for applications and system integration with an international application system.

1.9. Seed Regulatory and Testing Division

The Seed Regulatory and Testing Division (SRTD) administers the Federal Seed Act and other marketing programs to facilitate the trade of agricultural and vegetable seed in domestic and international markets. These activities ensure that seed buyers can make informed choices when purchasing seed and American seed businesses are able to market their seed on a level playing field. SRTD partners with all 50 State departments of agriculture and several industry organizations to leverage its limited resources into a broad network of regulatory and marketing outreach that stabilize and support the robust 12-billion-dollar U.S. seed market.

Recent activities conducted by SRTD to facilitate domestic and international marketing include the updating of the Federal Seed Act regulations. Last updated in 2011, the revised regulations ensure that outdated requirements which hinder domestic trade are removed and updated with process requirements that consider current industry practices. Due in part to this revision, the U.S. businesses may utilize new technology that better support efficient seed trade.

In FY 2020, SRTD began building a new laboratory information system to replace an older system which was unable to receive upgrades due to outdated software. Instead of relying solely on contractors to manage the project, SRTD used the knowledge and skills of team members within the Science and Technology Program to build the database, which saved over $100,000 in contracting fees. The system went live in October 2020. The new system will also allow for more straight forward billing through mass uploads which saves time and reduces printing. The new system also allows SRTD to add updates, as needed, to remain flexible and responsive to stakeholder needs.

1.10. Perishable Agricultural Commodities Act Program

This Perishable Agricultural Commodities Act Program (PACA) is designed to: (1) protect producers, shippers, distributors, and retailers from loss due to unfair and fraudulent practices in the marketing of perishable agricultural commodities; and (2) prevent the unwarranted destruction or dumping of farm products handled for others. Commission merchants, dealers, and brokers handling fresh and frozen fruits and vegetables in interstate and foreign commerce must obtain a PACA license and abide by the fair-trading practices established by the PACA. Traders who have been found to have committed unfair

trade practices face license suspension or revocation and may be required to post surety bonds before resuming operations. AMS developed a modernized data management platform, ePACA, that includes an online self-service portal through which members of the produce industry can apply for or renew a PACA license, file complaints when they have not been paid in full by their buyers, and pay PACA fees. The ePACA system reduces the time it takes AMS to approve and issue a license, shortens the complaint process, and facilitates faster payment of outstanding debts to farmers and produce sellers. The ePACA system also provides enhanced search capabilities of PACA licensees with 24-hour access to real-time information that produce sellers can use to make informed business decisions.

1.11. Packers and Stockyards Division (PSD)

AMS provides impartial third-party regulatory overview of electronic grading evaluation being used in the sale of livestock, meat, and poultry. In 2001, PSD began working with the livestock and poultry industries through ASTM International by developing voluntary consensus standards for livestock, meat and poultry grading devices. Acting within its regulatory framework, PSD amended regulations promulgated under the Packers and Stockyards Act by referencing three standards developed by ASTM International. To ensure fair business practices, PSD continually conducts trade practice investigations of packers' electronic grading evaluation practices to determine compliance with the Act and regulations. Today, PSD continues to participate in ASTM International F10 activities exploring new instrument grading standards for lamb and pork tenderness. PSD is committed to working with our ASTM partners in the industry to not only meet challenges but to succeed in creating an industry that provides quality meat and poultry products to consumers and increased producer returns.

1.12. Warehouse and Commodity Management Division (WCMD)

The Warehouse and Commodity Management Division (WCMD) supports the agricultural community through a variety of programs which are essential to promoting agricultural production and food security. WCMD administers the U.S. Warehouse Act of 1916 and certain provisions of the Commodity Credit Corporation (CCC) Charter Act of 1933. WCMD's mission is to oversee the formulation of national policies and procedures to administer a nationwide warehousing system, establish posted county prices for major farm program commodities, and manage CCC commodity inventories and cotton economic assistance programs. WCMD acquires, barters, sells, and manages CCC-owned inventories; routinely analyzes locations, conditions, and quantity of the stocks as part of its quality assurance processes; and establishes the Posted County Prices (PCPs) that are used to determine loan repayment rates for CCC marketing assistance loans and loan deficiency payments.

In accordance with USDA Strategic Goal 1 to work efficiently, effectively, with integrity and a focus on customer service, WCMD intends to modernize its present information technology infrastructure. Modernization efforts align with Departmental security requirements and create efficiencies within operations by removing stovepipes, strengthening internal controls, and eliminating conflicting functionality.

1.13. Federal Grain Inspection Service (FGIS)

FGIS facilitates the marketing of grains, oilseeds, pulses, legumes and related products; ensures fair and transparent markets free from deceptive and fraudulent practices; and provides reliable descriptors of crop quality and value to promote economic health and prosperity in American agriculture. FGIS accomplishes this, in part, by establishing grain quality standards and by providing an impartial inspection and weighing service through a network of Federal, State, and private entities. U.S. farmers produce a wide variety of agricultural products, and the vast American infrastructure permits these products to be processed and distributed throughout the United States and international markets effectively and efficiently. In FY 2020, the grain markets serviced by FGIS represented an approximate value of $111 billion, with exports contributing about $34 billion to the U.S. economy.

FGIS maintains a strong presence, both domestically and internationally, in the development, evaluation, and implementation of practical grain quality assessment and inspection methods. Our laboratories work with the latest technologies, and through these technologies and our ongoing efforts, we are helping to improve the quality of U.S. grain available to the global market. To enhance marketing of grain into the future, we are also conducting internal research and participating in development and collaborative efforts with other governmental entities, laboratories, and private businesses. The research and analysis we conduct is in response to clear and widespread market needs. In general, FGIS research is highly "applied," in that FGIS's successful projects result in direct and immediate use by the U.S. grain industry. FGIS also develops written information for customers and stakeholders, including scientific publications, publications in trade journals, and reports to stakeholders.

As agricultural crops evolve and varieties with enhanced traits are developed, reliable tests must be developed to detect and quantify the quality traits important to the market. FGIS conducts an evaluation program to assess the performance of rapid test kits that are designed for detecting and/or quantifying the presence of mycotoxins in grain and for detecting the presence of specific genetically engineered (GE) traits in grain. FGIS research on testing methods results in new applications of existing technologies, such as near infrared spectroscopy and nuclear magnetic resonance, and improvements in those technologies to meet identified market needs for grain quality assessments.

Current Technology Transfer Initiatives

Inspection Lighting.

Visually identifying quality factors within grain and other commodities requires specific lighting characteristics to appropriately illuminate the sample being graded. FGIS has identified a need for light emitting diode (LED) lights as an alternative to the fluorescent lights currently used within the official inspection system. In FY 2020, FGIS developed an experimental plan to conduct a field study of one commercially available LED light to assess the equivalence of official corn, soybean, and wheat damage inspections under the LED light compared to the current fluorescent lights. In FY 2020, FGIS also developed an experimental plan using five commercially available LED lights to identify the appropriate specifications for LED lights that will provide inspection results that are equivalent to the current fluorescent lights. Both studies will be conducted in FY 2021.

Falling Number Testing Program.

The falling number test measures the effect of the enzyme, alpha-amylase, on wheat. High alpha-amylase activity is associated with sprout damage and adversely affects the end-use quality of wheat. As a result, the falling number test is an important factor in the domestic and international trade of wheat. In FY 2020, FGIS completed a collaborative project with the Agricultural Research Service to evaluate the use of corn starch as a reference material for the falling number test. The results of the study showed that corn starch is stable at room temperature and could be used as an alternative to ground wheat meal in quality control of falling number testing.

Rapid Test Kits.

FGIS continues work with manufacturers to evaluate and approve rapid test kits that detect mycotoxins and GE traits in grain. Only FGIS-approved mycotoxin test kits that meet specific performance criteria can be used for official grain inspection. FGIS provides a monthly update of all approved rapid test kits on its public website. In FY 2020, FGIS evaluated 17 test kits and 13 were approved for the detection of mycotoxins in grain including, aflatoxins, deoxynivalenol, fumonisins, and zearalenone.

Harmonizing Biotech Reference Methods.

There is a need for highly specific and accurate tests for the various GE crops grown in the United States. FGIS has developed intra-laboratory validated, real-time polymerase chain reaction (PCR)

methods and has evaluated the accuracy, reliability, and proficiency of publicly available methods used to detect and identify GE grains and oilseeds. These PCR reference methods are used in a Corn and Soy Biotech Proficiency Program, wherein FGIS seeks to improve the overall performance of testing for GE grains and oilseeds. The FGIS proficiency program report contains inter-laboratory comparisons to determine the performance of individual laboratories' ability to detect and/or quantify transgenic traits in corn or soy as well as to monitor laboratories' continuing performance. The program does not assess the effectiveness of different detection methods for GE traits, nor does it determine the characteristics of fortified samples to a particular degree of accuracy. However, the FGIS Proficiency Program helps organizations identify areas of concern and take corrective actions to improve testing precision, capability, and reliability.

Export Wheat, Soybean, and Corn Quality Surveys.

FGIS provides testing services for grain through annual export survey programs in collaboration with U.S. Wheat Associates, U.S. Soybean Export Council, and the U.S. Grains Council. FGIS organizes the surveys by collecting samples and performing a range of analytical tests, including tests for pesticide residues and heavy metals. FGIS has assisted with the wheat survey for over 20 years, the soybean survey for 12 years, and the corn survey for 4 years. The purpose of the survey programs is to assess the quality of grain and grain-related commodities in order to facilitate the U.S. grain market. The market development organizations use the data to advise importers worldwide on what is available for sale, the cost, and the advantages that U.S. wheat, corn, and soybeans have over the competition.

Outreach Activities

At the request of the U.S. Department of State, two FGIS scientists served as members of the "Experts for the Network of Laboratories for the Detection and Identification of Living Modified Organisms." The objective of this group is to facilitate discussions focused on new detection and identification techniques, current capacities to detect and identify living modified organisms and sharing of experiences regarding the detection, identification and monitoring of the organisms, components and products of synthetic biology.

FGIS responds to customers' needs for technical assistance in foreign markets. Exporters, importers, and end-users of U.S. grains and oilseeds, as well as other USDA agencies, USDA cooperator organizations, and other governments ask for FGIS expertise. FGIS provides grain-marketing and grain-grading seminars, meets with foreign governments and grain industry representatives to resolve grain-quality and weight discrepancies, helps other countries develop domestic grain and commodity standards and marketing infrastructures, assists importers with quality specifications and trains local inspectors in U.S. inspection methods and procedures. In FY 2020, FGIS representatives traveled to Dubai to present procedures for sampling and inspecting U.S. wheat and milled rice exports to members of the Iraqi Grain Board. Starting in March 2020, due to the COVID-19 pandemic, FGIS could no longer travel internationally to meet with importers and end users of U.S. grain in person. FGIS representatives participated in virtual conferences with participants from the Southeast Asia and Caribbean regions, as well as, Mexico and Venezuela, to present our role in the inspection of U.S. grain exports. Outreach activities serve to strengthen the U.S. reputation for being a reliable supplier of high-quality grain, to

reinforce the integrity of FGIS as an independent quality-inspection authority, and to minimize discrepancies in inspection results between FGIS and importers.

FGIS personnel frequently meet with delegations visiting from other countries to brief them on the U.S. grain marketing system, our national inspection and weighing system, U.S. grain standards, and our mission. Many of these delegations are sponsored by USDA Cooperator organizations like the U.S. Wheat Associates and U.S. Grains Council, that arrange visits to grain production areas, FGIS field offices, onsite laboratories at export grain elevators, and our National Grain Center in Kansas City, Missouri. At the National Grain Center, delegations sometimes receive technical training on analytical testing procedures and grain inspection methods and procedures. Presentations include explanations of the various services available from FGIS, our use of the latest technology to provide grain traders with accurate and reliable inspection and weighing information, and information on FGIS services that importers can use to contract for the quality they desire. These briefings foster a better understanding of the entire U.S. grain marketing system and serve to enhance purchasers' confidence in U.S. grain.

Ultimately, these efforts help move our Nation's harvest to end-users around the globe. During FY 2020, FGIS personnel hosted 11 events, of which 3 engaged international trade teams.

Publications

The FGIS Performance Verified Mycotoxin Rapid Test Kits matrix is located on FGIS's website at: https://www.ams.usda.gov/sites/default/files/media/FGISApprovedMycotoxinRapidTestKits.pdf The matrix is updated on a monthly basis.

The FGIS Performance Verified Biotech Rapid Test Kits matrix is located on FGIS's website at: https://www.ams.usda.gov/sites/default/files/media/FGISApprovedBiotechRapidTestKits.pdf The matrix is updated as new tests are approved.

The FGIS Biotechnology Proficiency Report is located on FGIS's website at: https://www.ams.usda.gov/services/fgis/standardization/proficiency

The FGIS approved moisture calibrations is located on FGIS's website at: https://www.ams.usda.gov/services/fgis/standardization/moisture-equipment The calibrations are updated May 1 and August 1.

1.14. Standards Development

AMS food and fiber standards are widely used by the agricultural industry in domestic and international trading, futures market contracts, and as a benchmark for purchase specifications in most private contracts. Grade standards are also the basis for AMS Market News reports, grading services, and Federal commodity procurement. Pursuant to the Agricultural Marketing Act of 1946, AMS develops quality grade standards for commodities "to encourage uniformity and consistency in commercial

practices," as needed by the agriculture and food industry, and modifies those standards when industry practices or consumer preferences change. Before standards are implemented, AMS conducts studies and announces proposed standards. Public comments are solicited to verify that quality grade standards will facilitate commerce. There are currently more than 500 quality grade standards in place for cotton, dairy products, eggs, fresh and processed fruits and vegetables, livestock, meat, olive oil, peanuts, poultry, rabbits, and tobacco. AMS has recently partnered with the American Meat Science Association to conduct in-plant trials and collect data to assess the accuracy of camera instruments in applying the grade standards for beef. The results of this study will be used to determine if adjustments should be made to tolerances for validating the instrument. Additionally, program specialists designed initial trials to use egg grading technology in the application of official USDA grades (i.e., Grade AA, Grade A eggs). They collaborated with private-sector leaders to evaluate data collection and analysis capability, which in turn, could result in more uniform/accurate USDA grading, reduction of repetitive motion injuries for employees, and more streamlined service. As a result, the Agency expects to implement instrument-assisted grading of eggs in the future to remain in step with improvements in the egg processing industry.

1.15. International Standardization Activities

AMS provides technical expertise to international standards organizations to protect the interests of U.S. agricultural producers. AMS remains a leader in global marketing standards initiatives and represents the United States in meetings of the Codex Alimentarius, the International Dairy Federation, the United Nations Economic Commission for Europe (UNECE), the Organization for Economic Cooperation and

Development, the International Organization for Standardization, the International Union for the Protection of New Varieties of Plants (UPOV), the International Seed Testing Association, the International Meat Secretariat, the American Society for Testing and Materials International, the U.S. Canadian Regulatory Cooperation Council, the Inter-American Commission on Organic Agriculture, the International Cotton Advisory Committee, international cotton outreach, and several bilateral consultative committees on agriculture through direct outreach and interventions. Much of the work in international standardization involves developing and validating methods of analysis, leveraging new technologies for agricultural use, establishing specialized characteristic descriptions, developing interpretative literature and capturing and analyzing increasingly large datasets.

1.16. Auditing, Certification, Grading, Testing and Verification Services

AMS provides impartial services verifying that agricultural products meet specified grades and requirements. These services which are voluntary and fee for service include the grading program, the USDA Process Verified Program (PVP) and the Quality Monitoring Program (QMP). The grading program confirms that products meet USDA grade standards. The audit and verification-based PVP is a voluntary testing and process verification programs modeled on the International Organization for Standardization (ISO) 9001. PVP allows companies to develop their own standards and marketing claims regarding products and production practices and is a flexible, cost-effective, quality assurance service that provides third-party monitoring of product quality and quality systems for fresh, frozen, and processed fruits and vegetables as they are received, handled, and/or produced. The Quality Management Systems Standard. program supports brand and product quality, monitors quality systems,

measures supplier performance, and meets any unique quality assurance needs of the customer. Technology use by AMS in meat grading improved accuracy and efficiency of grading services by evaluating and expanding the use of instrument technology, including assessing current beef camera validation procedures. AMS also approved a camera for use in one lamb production plant.

1.17. Shell Egg Surveillance

AMS supports egg marketing by ensuring that cracked, leaking, or other types of "loss" (restricted) eggs are diverted from table egg consumption and by verifying that marketed eggs have a quality level of at least U.S. Consumer Grade B. AMS conducts this program, in cooperation with State Departments of Agriculture, to ensure that shell egg handling operations are inspected at least four times annually and hatcheries are inspected at least once each year to control the disposition of certain types of under grade and restricted eggs. This program diverts eggs that are not at least U.S. Consumer Grade B and cannot be sold in shell form to egg breaking plants, which reassures buyers and supports efficient markets. Initial trials have begun for a program specialist designed egg grading technology for use in the application of official USDA grades (i.e., Grade AA, Grade A eggs). This collaboration with private-sector leaders to evaluate data collection and analysis capability could result in more uniform/accurate USDA grading, reduction of repetitive motion injuries for employees, and more streamlined service. The Agency expects to implement instrument-assisted grading of eggs in the future to remain in step with improvements in the egg processing industry. When outbreaks of pathogenic diseases are confirmed in wild and domestic avian flocks in the United States, AMS has chosen in most cases to postpone SES

inspections at handlers and hatcheries in the impacted areas as a precautionary measure against the inadvertent spread of the disease.

2.0. Animal and Plant Health Inspection Service (ars2.0.1. Introduction

USDA broadly defines technology transfer as the ***adoption of research outcomes (i.e., solutions) for public benefit.*** Seemingly a simple statement, that 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 by partners through collaborative research, formal cooperative research and development agreements (CRADA) authorized by the Federal Technology Transfer Act (1986), direct Federal, Tribal, 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. This report summarizes the Technology Transfer accomplishments of all APHIS Programs for fiscal year 2020.

2.0.2 APHIS COMBINED METRICS

Table 1: Disclosures and Patenting – APHIS Programs

		FY16	FY17	FY18	FY19	FY20
1	Invention Disclosures Received	4	4	4	6	3
2	Total Patent Applications Filed	5	5	0	5	5
3	US	4	5	0	5	4
4	Foreign	1	0	0	0	1
5	Total Patent Cooperation Treaty (PCT) Applications Filed	0	2	0	0	0
6	Total Patents Issued	3	1	1	3	4
7	US	3	1	1	1	2
8	Foreign	0	0	0	2	2

Table 2: Licenses – APHIS Programs						
		FY16	FY17	FY18	FY19	FY20
8	Invention Licenses, Total Active	3	3	4	4	4
9	New Invention Licenses	0	0	1	0	0
10	New Invention Licenses Granted to Small Businesses	0	0	1	0	0
11	Income Bearing Licenses, Total Active	3	3	4	4	4
12	New Income Bearing Licenses	0	0	1	0	0
13	Exclusive, Total Active	0	0	1	0	0
14	Partially Exclusive, Total Active	0	0	0	0	0
15	Non-Exclusive, Total Active	0	0	0	0	0
16	Other Licenses, Total Active	0	0	0	0	0
17	New Other Licenses	0	0	0	0	0
18	New Other Licenses Granted to Small Businesses	0	0	0	0	0
	Elapsed Amount of Time for Granting Invention Licenses					
19	Average (months)	ND	ND	ND	ND	ND
20	Minimum (months)	ND	ND	ND	ND	ND
21	Maximum (months)	ND	ND	ND	ND	ND
22	Licenses Terminated for Cause	ND	ND	ND	ND	ND

Table 3: Income from Licensing – APHIS Programs						
		FY16	FY17	FY18	FY19	FY20
22	Invention License Income	5037	25	508	140	100
24	Other License Income	0	0	0	0	3
25	Total Earned Royalty Income (ERI)	5037	25	508	140	100

26	ERI from Top 1% of Licenses	5037	25	508	140	100
27	ERI from Top 5% of Licenses	5037	25	508	140	100
28	ERI from Top 20% of Licenses	5037	25	508	140	100
29	Minimum ERI	37	25	508	240	100
30	Maximum ERI	5000	25	508	240	100
31	Median ERI	ND	NA	ND	ND	ND
	Disposition of ERI					
32	Percentage Distributed to Inventors	49	100	100	100	100
33	Percentage Distributed to Lab/Agency	51	0	0	0	0

Table 4: Collaborative Agreements – APHIS Programs

		FY16	FY17	FY18	FY19[1]	FY20
34	Total Active CRADAs[1]	9	6	7	9	12
35	New CRADAs	2	0	1	3	6
36	New CRADAs Involving Small Businesses	2	0	1	3	2
37	Other Collaborative Agreements[1]	343	217	195	134	234

[1]Cooperative Research and Development Agreement
[2]WS began reporting new agreements under collaborative agreements

Table 5: Other Intramural Performance Measures deemed Important to the Agency – APHIS Programs

		FY16	FY17	FY18	FY19	FY20
	New Confidentiality Agreements	7	22	12	37	45

	New Material Transfer Agreements	33	24	47	53	66
	New Material Transfer Research Agreements	7	11	15	13	13
	Peer-Reviewed Scientific Publications	145	141	197	178	241
	Non-Indexed Publications	8	20	23	11	18

2.1. BIOTECHNOLOGY REGULATORY SERVICES (BRS)

2.1.1. Mission Statement

The mission of BRS is to protect and enhance U.S. agricultural and natural resources using a science-based regulatory framework to ensure the safe importation, interstate movement, and environmental release of certain organisms that have been modified or produced using genetic engineering.

2.2.2. Nature and Structure of Program

Through the Biotechnology Regulatory Services (BRS) program, the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) protects against risks to U.S. plant health by overseeing the safe import, interstate movement, and environmental release/field testing of certain organisms developed using genetic engineering. APHIS-BRS coordinates these responsibilities along with the other designated Federal agencies as part of the Federal Coordinated Framework for the Regulation of Biotechnology.

Although BRS does not perform research, it works with researchers on regulatory aspects as they develop new products. Researchers and product developers, Federal or private, should understand and work with the appropriate regulatory agencies that may have oversight of an organism developed using genetic engineering at different stages in the development of a product. This can facilitate efficient development of the appropriate information necessary for regulatory review.

BRS provides compliance assistance to organizations involved in biotechnology research and development, including small businesses and academic researchers, to facilitate compliance with APHIS regulations (7 Code of Federal Regulation (CFR), part 340). The BRS Biotechnology Quality Management Support Program (BQMS) is a voluntary flexible, customizable, and cost-efficient voluntary program. The BQMS Program is designed to help organizations of any size universities, small businesses, and large organizations develop sound quality management practices to enhance their ability to comply with the APHIS organisms developed using genetic engineering found at 7 CFR part 340.

The BQMS Program is a modular system which allows each unique user the option of selecting from a list of web-based compliance assistance tools referred to as modules. These modules are designed in a user-friendly question-and-answer format to help in creating a documented self-certifying quality management system to manage critical control points consistent with the requirements at 7 CFR part 340.

Examples of BRS contributions to technology transfer in 2020

Modernized USDA's biotech regulations by finalizing the SECURE Rule and facilitating the transition to the new regulatory framework: launched user-friendly SECURE website, posted resources to request confirmation of regulated status and prepare claims for Confidential Business Information, and interacted with stakeholders. The APHIS BRS SECURE Rule modernized USDA's biotechnology regulations using science-based and risk-based approaches. These regulations will adapt to future

agriculture innovation, provide economic opportunities for rural America, and support USDA's goal of feeding the world.

- Protected the U.S. citrus industry by authorizing a permit for the statewide release of GE citrus tristeza virus to combat citrus greening in Florida after completing a Plant Pest Risk Assessment and final Environmental Impact Statement.

- Delivered excellent customer service and fostered innovation by authorizing over 730 permits and notifications meeting the designated timeframe for 97 percent of them exceeding the FY 2020 target (FY 2020 target = 90 percent). Also met stakeholder needs through this process by providing excellent customer service through consultation calls and emails.

- Assured the safety of sophisticated new technologies by managing more than 64 comprehensive authorizations for the DOD DARPA insect allies program which was completed this year (2017-2020). This program had a budget of more than $30M that was used to fund researchers who are developing new approaches to responding to plant stressors in the environment. This involved developing a highly complex set of permits for the movement and use of both GE and non-GE plants and viruses among multiple locations, necessitating close coordination with ROP and PPQ to ensure effective, efficient, and consistent regulatory oversight.

- Facilitated the advancement of relevant scientific knowledge by identifying and communicating BRS research priorities to the USDA, National Institutes of Food and Agriculture (NIFA) Biotechnology Risk Assessment Research Grants Program (BRAG), while enhancing cooperation with colleagues from the USDA, ARS; EPA; and FDA.

2.2.3. Economic Impact Studies

Regulatory Impact Analysis and Final Regulatory Flexibility Analysis Final Rule. Movement of Certain Genetically Engineered Organisms (7 CFR part 340) October 2019

Under the Plant Protection Act (PPA, 7 USC 7701-7772), the Secretary of Agriculture is authorized to regulate the movement into and through the United States of plants, plant products, and other articles to prevent the introduction or dissemination of plant pests. As one part of its implementation of the PPA, APHIS regulates the safe introduction (environmental release, interstate movement, and importation) of certain genetically engineered (GE) organisms that might be plant pests (7 CFR part 340). APHIS is revising its regulations of GE organisms to respond to emerging trends in genetic engineering, to more efficiently use APHIS resources, and eliminate unnecessary regulatory burdens.

The revisions to 7 CFR part 340 create the framework for more focused, risk-based regulation of the GE organisms that pose plant pest risk. Under this rule, certain categories of plants are exempted from the regulations in part 340. Developers are able to determine, when appropriate, whether their products fit into one of the exempted categories and are therefore not subject to APHIS' regulations.

The rule also provides for a process to determine the regulatory status of a plant under part 340. GE plants having the same plant-trait-mechanism of action combination as those previously found by APHIS to be not subject to the regulations will not be regulated, nor will they be required to undergo a regulatory status review (RSR). GE plants found likely to pose a plant pest risk and GE plants that are not eligible for an RSR, will be allowed to move only under permit. For plants that do not fall into any of the exempted categories and are eligible for an RSR, developers have the option of either requesting a review or requesting a permit for the movement (including importation, interstate movement, or environmental release) of their organism in lieu of an RSR. Developers of GE organisms that are plant pests will continue to need permits to import, move interstate, or environmentally release those organisms. Shipping standards under this rule are less prescriptive and more generally applicable, and the rule provides for the issuance of multi-year permits.

The amendments in this rule will benefit developers, producers, and consumers of certain GE organisms; public and private research entities; and APHIS. There will be no decrease in the level of protection provided against plant pest risks. The regulatory framework, including the RSR process used to determine regulatory status, established under this rule will provide cost savings to some plant developers and will allow for reallocation of APHIS resources to Biotechnology Regulatory Services (BRS) priorities.

Farmers who adopt GE crops may benefit from the rule. GE crop adoption vary by crop and technology and can affect yields, net returns, and pesticide use. Among the types of innovations expected are crops with greater resistance to disease and insect pests; greater tolerance of stress conditions such as drought,

high temperature, low temperature, and salt; and more efficient use of fertilizer. These types of traits can lower farmer input costs (water, fertilizer, pesticide) and increase yields during times of adverse growing conditions.

In addition to the compliance costs associated with regulation, there are opportunity costs of delayed innovation if the approval process for a plant is longer than necessary to ensure safety with reasonable scientific certainty. Regulatory delays mean that the benefits of innovation occur later than they would otherwise and most likely at lower levels. The forgone benefits due to delayed innovation can be substantial and developers, producers, and consumers all lose from regulatory delays. The forgone benefits stemming from even a relatively brief delay in product release can overshadow both research and regulatory costs. Regulatory costs are expected to be lower under this rule, thereby potentially spurring developer innovation, especially among small companies and universities. Consumers will benefit from a wider variety of available products, including ones with improved taste, storage longevity, or nutritional content.

2.2. INTERNATIONAL SERVICES

2.2.1. Mission Statement

The mission of APHIS - International Services (IS) is to protect U.S. agricultural and natural resources by working with foreign governments and international organizations to prevent the spread of high-risk plant pests and animal diseases; facilitate the safe international movement of agricultural commodities through science-based regulations and internationally accepted standards; and enhance global health and U.S. biosecurity through the development of science-based regulatory systems and policies around the world.

2.2.2. Nature and Structure of the Program

IS' overseas presence empowers APHIS to monitor and respond to pest and disease threats, develop international strategies and partnerships to prevent their spread to the United States, and support U.S. agricultural trade by resolving technical trade barriers. Through its services, IS contributes directly to global food security by promoting safe global trade and facilitating the development of science-based regulatory systems around the world. IS works closely with its sister units, including Veterinary Services (VS), Plant Protection and Quarantine (PPQ), Biotechnology Regulatory Services (BRS), Wildlife Services (WS) and other headquarters staffs, to ensure that its work overseas reflects the priorities of these domestic programs. This collaboration is key to IS' success and is achieved through

joint planning, enhanced communications, clear direction to the field, and implementing coordinated strategies.

IS uses technology transfer to support APHIS' work overseas by creating bonds and supporting partnerships, collaborations, and cooperative programs. As part of its mission to safeguard U.S. agriculture and expand the safe exportation of unprocessed agricultural products, IS collaborates with international partners through bilateral and multilateral treaties and agreements to improve animal and plant health systems around the world. IS partners with international organizations, including the International Atomic Energy Agency (IAEA), World Organization for Animal Health (OIE), the Food and Agricultural Organization of the United Nations (FAO), The Pan American Health Organization (PAHO), and the International Regional Organization for Agricultural Health (OIRSA) as well as with our international trading partners, to help prepare and implement appropriate technologies to control or eliminate sanitary and phytosanitary (SPS) threats to the safe trade of agricultural products.

Examples of International Services Action Programs:

- During 2020, IS personnel from the U.S.-Panama Screwworm Eradication Program continue to capitalize upon the transfer of technology and protocols to USDA, ARS scientists in cryopreservation and collection of genetic material in the field. These actions are pivotal in optimization of leveraging preserved genetics going forward as well as retrospective analyses and assessments of the effectiveness of advancements in the Sterile Insect Technique (SIT) paradigm. Sustainability and advancement of the program depend upon the technologically

advanced and reliable cataloguing and retrieval of banked genetics for diversity and posterity.

- Screwworm personnel continue to serve as a resource and facilitator in the transfer of technology, protocols, education and training cooperatively with IAEA to officials of countries interested in SIT safeguarding activities.

- IS screwworm has been featured and highlighted via various virtual fora including for the APHIS Science Committee to increase awareness of the importance, utility and essential nature of achieving efficiencies and sustainability of the program, as well as emphasize the importance of vigilance and preparedness for potential Screwworm introductions.

- In 2020, we also assisted with technology transfer (protocols and information) to the country of Uruguay which is in the process of initiating a screwworm eradication program.

Caribbean

- In 2020, IS and VS continued to work with the Dominican national animal disease diagnostic laboratory to update their standard operating procedures and consulting on the proposed upgrade of laboratory equipment given the ongoing need for a regional reference laboratory in the face of emerging foreign animal disease threats. The rise of African Swine Fever (ASF), in particular,

has increased this urgency; however, Classical Swine Fever (CSF) and Avian Influenza (AI) (both Highly Pathogenic [HPAI] and Low Pathogenicity [LPAI] Avian Influenza).

- In the Caribbean region, to continue support for CaribVET efforts to strengthen Avian Influenza surveillance and risk mapping capabilities

- In South America to continue support for training and strengthening of the network of diagnostic laboratories (RESUDIA),

- Continue training and activities for emergency planning and preparedness, such as recent GEMP training in Colombia, throughout all of LAC

Mexico

- In FY 2020, APHIS-VS continues to support officials from the Mexican National Animal Health Laboratory through VS' National Veterinary Services Laboratories (NVSL) on Whole Genome Sequencing of M bovis and the associated bioinformatics.

2.2.5. Success Stories Demonstrating Downstream Outcomes From Technology Transfer Activities

International Technical and Regulatory Capacity Building (ITRCB)

The ITRCB, a headquarters staff of IS, acts as a clearinghouse to review requests for APHIS technical assistance. The resulting courses, workshops, and technical meetings are key to bringing new and innovative techniques and technology to our foreign counterparts. In an ongoing example, in FY 20, ITRCB and APHIS' Vietnam office hosted an ASF 3-D (Depopulation, Disposal, and Decontamination) training highlighting depopulation technology. Similar virtual consultations have occurred several times with India, as well. When appropriate, ITRCB supports Agency efforts by facilitating technical cooperation activities with trading partners and developing countries. This training, including the use of new technology with foreign counterparts, comprises a significant part of ITRCB's mission. However, technology transfer is generally limited.

2.3. PLANT PROTECTION AND QUARANTINE

2.3.1 Mission Statement

APHIS' Plant Protection and Quarantine (PPQ) program safeguards U.S. agriculture and natural resources against the entry, establishment, and spread of economically and environmentally significant pests, and facilitates the safe trade of agricultural products.

2.3.2. Nature and Structure of Program

PPQ's technology development is facilitated and implemented through cooperation between its three divisions; Policy Management (PM), Field Operations (FO), and Science and Technology (S&T)**.** PPQ Science and Technology (S&T) provides scientific analysis and support for PPQ regulatory decisions and operations, and develops practical tools for plant pest exclusion, identification, detection, and management for PPQ.

PPQ S&T is headquartered on the campus of North Carolina State University in Raleigh, North Carolina. S&T consists of approximately 240 scientists, analysts, and support staff at 7 principal laboratories and additional satellite locations. S&T supports regulatory plant protection activities by developing methods and conducting analyses in the following areas of plant health: agricultural commodity treatment and inspection, pest risk analysis, pest identification and diagnostics, pest detection, and pest management. S&T also administers the National Clean Plant Network (NCPN), an

association of specialty crop networks that promote the use of pathogen-tested, healthy plant material for food crops in the United States.

S&T activities are primarily focused on providing scientific support for PPQ needs and decision making, but also support stakeholders such as State plant regulatory programs and the agricultural and nursery industries. S&T conducts its work with internal stakeholders but also engages other Federal agencies (e.g. ARS, NIFA, Forest Service, DOE National Labs, DHS and EPA), Tribal Nations, academia, international institutions, and industry to acquire knowledge, best management practices, products and protocols, and to develop methods and protocols needed for plant protection and management of invasive pests.

PPQ is committed to use of the best science, tools, and technologies to strengthen the efficiency and effectiveness of PPQ's work. PPQ transfers new methods and technology through several mechanisms, including technical documents, protocols, risk assessments, and pest survey guidelines that are distributed directly to stakeholders or are made available through PPQ websites. Another important mechanism to transfer information is through the publication of results in peer-reviewed scientific journals. We also directly transfer technology and scientific knowledge through hands-on training at our labs, presentations at technical or professional conferences, publications in proceedings, trade publications, and by providing direct technical assistance to the public, stakeholders, and industry through various outreach activities and events.

S&T provides training to stakeholders in technical aspects of plant health, including diagnostic testing, pest risk assessment, pest management, and quality management. For example, the Beltsville Lab provides hands-on training on molecular diagnostics for regulated plant diseases to diagnosticians from the National Plant Diagnostic Network (NPDN), State and Federal laboratories, and has conducted training workshops for diagnosticians to build biosecurity capacity in pathogen diagnostics, seed testing, quality management, and bioinformatics. S&T also provides training to stakeholders and local cooperators to transfer new pest management techniques including biological control, pesticide treatments, and survey techniques.

Formal agreements, including cooperative and interagency agreements and memoranda of understanding, are used to formalize collaborations with other government scientists, universities, private companies, and other stakeholders. In FY 2020, S&T provided oversight of over 282 cooperative and interagency agreements with a total value of over $42 million. PPQ also provides leadership and organization for 35 clean plant centers through the National Clean Plant Network in 20 States to support the development and distribution of disease-free stock of fruit trees, grapes, hops, berries, citrus, sweet potato, and roses.

2.3.3. Metric Tables

Table 1: Disclosures and Patenting – Plant Protection and Quarantine

		FY16	FY17	FY18	FY19	FY20
1	Invention Disclosures Received	0	0	0	0	0
2	Total Patent Applications Filed	0	0	0	0	0

3	US	0	0	0	0	0
4	Foreign	0	0	0	0	0
5	Total PCT Applications Filed	0	0	0	0	0
6	Total Patents Issued	0	0	0	0	0
7	US	0	0	0	0	0
8	Foreign	0	0	0	0	0

Table 2: Licenses – Plant Protection and Quarantine

		FY16	FY17	FY18	FY19	FY20
8	Invention Licenses, Total Active	0	0	1	1	1
9	New Invention Licenses	0	0	1	0	0
10	New Invention Licenses Granted to Small Businesses	0	0	1	0	0
11	Income Bearing Licenses, Total Active	0	0	1	0	0
12	New Income Bearing Licenses	0	0	0	0	0
13	Exclusive, Total Active	0	0	0	0	0
14	Partially Exclusive, Total Active	0	0	0	0	0
15	Non-Exclusive, Total Active	0	0	1	0	0
16	Other Licenses, Total Active	0	0	0	0	0
17	New Other Licenses	0	0	0	0	0
18	New Other Licenses Granted to Small Businesses	0	0	0	0	0
19	Elapsed Amount of Time for Granting Invention Licenses	ND	ND	ND	ND	ND
20	Minimum (months)	ND	ND	ND	ND	ND
21	Maximum (months)	ND	ND	ND	ND	ND
22	Licenses Terminated for Cause	ND	ND	ND	ND	ND

Table 3: Income from Licensing – Plant Protection and Quarantine						
		FY16	FY17	FY18	FY19	FY20
22	Invention License Income	0	0	350	0	0
24	Other License Income	0	0	0	0	0
25	Total Earned Royalty Income	0	0	350	0	0
26	ERI from Top 1% of Licenses	0	0	350	0	0
27	ERI from Top 5% of Licenses	0	0	350	0	0
28	ERI from Top 20% of Licenses	0	0	350	0	0
29	Minimum ERI	0	0	350	0	0
30	Maximum ERI	0	0	350	0	0
31	Median ERI	ND	ND	ND	ND	ND
	Disposition of ERI					
32	Percentage Distributed to Inventors	0	0	100	0	0
33	Percentage Distributed to Lab/Agency	0	0	0	0	0

Table 4: Collaborative Agreements – Plant Protection and Quarantine						
		FY16	FY17	FY18	FY19	FY20
34	Total Active CRADAs	ND	ND	ND	ND	ND
35	New CRADAs	ND	ND	ND	ND	2
36	New CRADAs Involving Small Businesses	ND	ND	ND	ND	ND
37	Other Collaborative Agreements	ND	ND	ND	ND	282

Table 5: Other Intramural Performance Measures Deemed Important to the Agency – Plant Protection and Quarantine

		FY16	FY17	FY18	FY19	FY20
	New Confidentiality Agreements	ND	ND	ND	ND	ND
	New Material Transfer Agreements	ND	ND	ND	ND	17
	New Material Transfer Research Agreements	ND	ND	ND	ND	ND
	Peer-Reviewed Scientific Publications	ND	ND	ND	ND	62
	Non-Indexed Publications	ND	ND	ND	ND	ND

2.3.4. Success Stories Demonstrating Downstream Outcomes From Technology Transfer Activities

PPQ's Identification Technology Program (ITP) provides technology-based pest identification products including image libraries, taxonomic tools, interactive keys, mobile apps, and pest survey screening aids. ITP also offers training and development support for producing these identification products. As of FY20, over 100 of the program's identification products are available via an open-access searchable portal (https://idtools.org). New releases in FY20 include Sawfly GenUS, an identification guide for Symphyta genera of North America and economically significant species; 96 new fact sheets and 4 new keys for the Exotic Bee ID tool; six new fact sheets for the Grasshoppers of the Western U.S. ID tool; a mobile app version of Aquarium and Pond Plants of the World; TingID, an identification guide for lacebugs intercepted at U.S. ports-of-entry; and an update to Longicorn ID to add identification support for larval cerambycid beetles. ITP's imageID, a searchable database of pest images to facilitate identification of pests intercepted at ports, continues to be expanded, and currently has over 160,000 pest images to assist with port operations. These products are used by APHIS scientists as well as scientists, inspectors, and surveyors in Customs and Border Protection, in State departments of agriculture, in

domestic and international academic institutions, and by national and regional plant protection organizations to screen and identify plant pests off-shore, at our ports, and domestically.

Biological control programs for invasive pests

PPQ biological control research focuses on developing technologies that support the safe use of biological control organisms to help mitigate the impacts of introduced invasive weeds and plant pests. Two major PPQ program targets are biological control agents for Asian citrus psyllid and emerald ash borer.

The Asian citrus psyllid (ACP) has invaded citrus-growing areas in the United States and is a vector of a bacterium that causes citrus greening disease or Huanglongbing (HLB). A key component to a management program is aggressive control of ACP vector. *Tamarixia radiata* is a species-specific ectoparasitoid of the ACP that was imported from Pakistan after satisfying APHIS PPQ permitting requirements for field release in Texas. The PPQ Mission Laboratory developed the technology to mass produce and release *T. radiata* using a field insectary cage approach for the biological control of ACP in south Texas. Since the project began in 2011, over 12.7 million beneficial insects have been produced by the Mission Lab for field release in Texas, Louisiana, and Mexico border areas. Assessments of area-wide management efforts in south Texas indicate an overall reduction in ACP populations of 89 percent since initiation of the program in 2011. The biocontrol rearing technology was also transferred to partners in California, which have now developed the capacity to release over 3 million parasitoids per year.

The emerald ash borer (EAB) is a destructive wood-boring pest of ash trees. PPQ has supported long-term efforts to establish emerald ash borer biocontrol agents to protect ash forest resources in cooperation with State partners. New research on EAB biological control agents has identified species that climatologically adapt to cooler or warmer U.S. regions and surrounding areas. Ongoing field evaluation of these EAB biological control agents are determining best management practices for their operational release. This discovery allows the program to better target biocontrol releases, while protecting the next generation of ash trees in eastern region forests. The EAB biocontrol rearing facility in Brighton, Michigan, produced four different parasitoid species in FY 2020 and released over 593,942 insects at 234 sites, in 142 counties, in 25 States. The FY 2020 biological control release sites included 31 new counties and one new State. The cumulative release total for the EAB program is biological control agents releases in 340 counties in 30 States and the District of Columbia.

Management Tools for Emergency Program Pests

PPQ conducts emergency response operations to respond to new pest outbreaks and continues to support development and transfer of new tools to manage European cherry fruit fly in New York, and spotted lanternfly in Pennsylvania. PPQ S&T has led the research to develop new detection and response tools to these pests, in collaboration with State and Federal partners. Recent advances for European cherry fruit fly (ECFF) include the development of a systems approach to allow cherry fruit movement from quarantine areas to reduce economic impacts to growers and pesticide recommendations for grove management. S&T also developed a molecular identification method to distinguish ECFF from related native flies and transferred this test to stakeholders.

For spotted lanternfly, which attacks several tree and fruit crops, PPQ has developed multiple effective insecticide application methods for host trees that have been transferred to State and Federal cooperators and are being applied in the program. S&T developed an improved circle trunk trap that greatly increased trapping levels and has been commercially produced and transferred to the program for survey use in 2020. A sentinel trap tree method was developed for SLF detection in new areas and was implemented for the 2020 field season in eight States.

One research development for spotted lanternfly turned out to also be applicable to another newly introduced pest, the Asian giant hornet in Washington State. PPQ scientists had previously developed a method to attach radio tags to spotted lanternfly to study their movements. When the Washington Department of Agriculture discovered an Asian giant hornet infestation, they needed a way to locate the nests to eradicate the pest. PPQ was able to provide some tags and instructions for attaching them to an insect. This allowed State cooperators to tag and track a hornet back to its nest, which they were able to destroy before the new queens could disperse and form nesting sites. PPQ S&T is continuing to improve management methods for these and other pests in order to support response and recovery efforts with State partners.

Regulatory diagnostics for National Plant Diagnostic Network

Since 2004, the PPQ Beltsville Laboratory has provided hands-on, advanced molecular diagnostic workshops to members of the National Plant Diagnostic Network (NPDN), State departments of agriculture, and Federal and commercial laboratories to provide trainings on PPQ-approved and

validated testing protocols for pathogens of regulatory significance that are known to affect a number of ornamental crops, specialty crops, and forest ecosystems in the United States. The Beltsville laboratory continues to hold several hands-on workshops each year to train NPDN diagnosticians from universities, State departments of agriculture, Federal laboratories, commodity groups and commercial diagnostics companies. These workshops have not only enhanced the molecular plant diagnostic capability in the Unites States, but also prepared the United States diagnosticians to provide surge capacity in the event of an unexpected plant pathogen outbreak or a national agricultural emergency.

In association with the Beltsville Lab, PPQ's National Plant Protection Laboratory Accreditation Program (NPPLAP) accredits NPDN, State, Federal, and commercial laboratories to perform regulatory diagnostics for *Phytophthora ramorum*, *Plum pox virus*, and citrus greening. In addition to providing annual proficiency tests for certification of diagnosticians and laboratories to perform regulatory diagnostic testing, NPPLAP also facilitates continual improvement of the programs by incorporating quality management training and new diagnostic techniques into the program.

2.4. VETERINARY SERVICES (VS)

2.4.1. Mission Statement

As the recognized animal health leader and trusted partner, VS protects and improves the health, quality, and marketability of our Nation's animals, animal products, and veterinary biologics by preventing, controlling, and/or eliminating animal diseases, and by monitoring and promoting animal health and productivity.

VS authorities derive from the Animal Health Protection Act and the Virus-Serum-Toxin Act. As the Nation's veterinary authority, VS improves the health, productivity, and quality of life for animals and people, in addition to maintaining and promoting the safety and availability of animals, animal products, and veterinary biologics. VS integrates One Health principles with USDA business objectives by contributing leadership, expertise, infrastructure, networks, and systems to collaborate effectively with local, State, Tribal, national, and international partners. Its comprehensive and integrated on-farm surveillance activities provide VS the capability to achieve national goals for animal disease prevention, detection, and early response.

2.4.2. Nature and Structure of Program

VS comprises three strategically focused organizational units. The three units are: Diagnostics and Biologics (D&B), Field Operations (FiOps), and Strategy and Policy (S&P). Organizing by major

services allows VS to better align with the changing dynamics of animal health and the needs of our customers. D&B combines and leverages the unique capabilities of two of VS science centers, focused on veterinary diagnostics and veterinary biologics, as well as the oversight for APHIS for the planning for the National Bio and Agro-Defense Facility (NBAF) replacing the Plum Island Animal Disease Center (PIADC). FiOps carries out functions ranging from early awareness and surveillance to the development and field/port implementation of animal health programs. S&P brings together VS' policy and permitting activities, including those in the international, species-specific, One-Health, and epidemiology areas. Although scientists and scientific activities are distributed across VS, the three VS science centers provide a solid scientific, technical, and analytical foundation needed to support VS' mission.

The National Veterinary Services Laboratories (NVSL)

The mission of NVSL is to safeguard U.S. animal health and contribute to public health by ensuring that timely and accurate diagnostic laboratory support is provided directly or by its coordination of the nationwide animal-health diagnostic system. NVSL accomplishes its mission through:

- Performing diagnostic laboratory testing for VS' program diseases and for suspected outbreaks of foreign/transboundary animal diseases;

- Serving as the U.S. national and international reference laboratory for animal disease diagnosis by providing unique veterinary diagnostic capabilities, providing other diagnostic laboratories with animal disease information, technical guidance, reagents, and reference materials;

- Providing national leadership in coordination of the National Animal Health Laboratory Network (NAHLN) and emergency laboratory response by training State, Federal, university, and foreign laboratory personnel, providing proficiency testing, and developing improved diagnostic technologies;

- Preparing for and responding to animal health emergencies and emerging threats to animal agriculture, including threats to the poultry and aquaculture industries, by being able to conduct and/or support diagnostic testing in an outbreak environment.

Among other potential technology transfer activities, NVSL develops and validates assays and manufactures and distributes over 500 biological reagents to support veterinary diagnostics, many of which are not available from any other source.

Before a test is utilized by VS for disease control or surveillance, it must be validated for that purpose. Samples for test validation for program diseases such as brucellosis and tuberculosis are in serum and tissue banks generated and maintained at NVSL. These samples are made available to commercial kit manufacturers for their initial validation, and additional test validation is conducted at NVSL. This is in addition to any testing for licensure required by the Center for Veterinary Biologics (CVB).

NVSL is also involved in the development and validation of assays used to detect diseases that are foreign to the United States. Some of these assays are utilized in the reference laboratory as confirmatory tests, while others are deployed to the NAHLN laboratories and utilized in surveillance programs, and for outbreak preparedness. NVSL is also responsible for managing the North American Foot-and-Mouth Disease Vaccine Bank (NAFMDVB) and the National Animal Vaccine and Veterinary Countermeasures Bank (NAVVCB). NVSL is a World Organisation for Animal Health (OIE) reference laboratory for 16 diseases of significance, and has been designated as a Food and Agriculture Organization of the United Nations (FAO) Reference Center for foot-and-mouth disease (FMD) and other vesicular diseases of the Americas and the Caribbean, avian influenza and Newcastle disease (ND), rinderpest, and bovine tuberculosis and paratuberculosis. NVSL is also an OIE-FAO Rinderpest Holding Facility.

Identification, feasibility testing, development, optimization, and validation of new assays and/or technologies are all accomplished within NVSL, often with the support of NAHLN laboratories in areas of study design and testing. NVSL staff collaborates with and provides scientific advice to other Federal and State Government agencies and university and research laboratories that are also developing new assays and technologies, and NVSL scientists partner with other reference laboratories around the world to obtain diagnostic specimens from naturally infected animals. These collaborative efforts result in enhanced expertise at NVSL and in reference collections that are available for assay development and validation.

Centers for Epidemiology and Animal Health (CEAH)

CEAH explores and analyzes animal health and related agricultural issues to facilitate informed decision-making in government and industry. CEAH has a multidisciplinary staff that includes agricultural economists, spatial analysts, geographers, informaticists, veterinary epidemiologists, statisticians, and biological scientists. CEAH collaborates with domestic partners on analysis methods and tools. CEAH also partners internationally with a variety of partners including the OIE and its member countries to improve international disease surveillance capabilities and analytic methods. In some cases, academic partners commercialize the products produced.

Center for Veterinary Biologics (CVB)

CVB's mission is to implement the provisions of the Virus-Serum-Toxin Act to assure that pure, safe, potent, and effective veterinary biologics are available for the diagnosis, prevention, and treatment of animal diseases. This mission mandates the use of sound scientific technology to:

- Ensure that biologics are free of disease producing agents, especially foreign animal diseases;
- Develop appropriate standards and procedures for product release;
- Issue licenses and permits;

• Monitor and inspect products and facilities; and

• Control field tests and release of veterinary biologics.

CVB-developed methods and biological standards are applied equally to all products, but by the same token can be adopted whole by the regulated commercial manufacturers, becoming part of their manufacturing and release process.

2.4.3. Metric Tables

Table 1: Disclosures and Patenting – Veterinary Services						
		FY16	FY17	FY18	FY19	FY20
1	Invention Disclosures Received	1	0	0	0	0
2	Total Patent Applications Filed	1	0	0	0	0
3	US	0	0	0	0	0
4	Foreign	1	0	0	0	0
5	Total PCT Applications Filed	0	0	0	0	0
6	Total Patents Issued	0	0	0	0	0
7	US	0	0	0	0	0
8	Foreign	0	0	0	0	0

Table 2: Licenses – Veterinary Services						
		FY16	FY17	FY18	FY19	FY20
8	Invention Licenses, Total Active	0	0	0	0	0

9	New Invention Licenses	0	0	0	0	0
10	New Invention Licenses Granted to Small Businesses	0	0	0	0	0
11	Income Bearing Licenses, Total Active	0	0	0	0	0
12	New Income Bearing Licenses	0	0	0	0	0
13	Exclusive, Total Active	0	0	0	0	0
14	Partially Exclusive, Total Active	0	0	0	0	0
15	Non-Exclusive, Total Active	0	0	0	0	0
16	Other Licenses, Total Active	0	0	0	0	0
17	New Other Licenses	0	0	0	0	0
18	New Other Licenses Granted to Small Businesses	0	0	0	0	0
	Elapsed Amount of Time for Granting Invention Licenses					
19	Average (months)	ND	ND	ND	ND	ND
20	Minimum (months)	ND	ND	ND	ND	ND
21	Maximum (months)	ND	ND	ND	ND	ND
22	Licenses Terminated for Cause	ND	ND	ND	ND	ND

Table 3: Income from Licensing – Veterinary Services

		FY16	FY17	FY18	FY19	FY20
22	Invention License Income	$0	$0	$0	$0	$0
24	Other License Income	$0	$0	$0	$0	$0
25	Total Earned Royalty Income	$0	$0	$0	$0	$0

26	ERI from Top 1% of Licenses	$0	$0	$0	$0	$0
27	ERI from Top 5% of Licenses	$0	$0	$0	$0	$0
28	ERI from Top 20% of Licenses	$0	$0	$0	$0	$0
29	Minimum ERI	$0	$0	$0	$0	$0
30	Maximum ERI	$0	$0	$0	$0	$0
31	Median ERI	$0	$0	$0	$0	$0
	Disposition of ERI	$0	$0	$0	$0	$0
32	Percentage Distributed to Inventors	$0	$0	$0	$0	$0
33	Percentage Distributed to Lab/Agency	$0	$0	$0	$0	$0

Table 4: Collaborative Agreements – Veterinary Services

		FY16	FY17	FY18	FY19	FY20
34	Total Active CRADAs	0	0	0	0	1
35	New CRADAs	0	0	0	0	1
36	New CRADAs Involving Small Businesses	0	0	0	0	1
37	Other Collaborative Agreements	22	32	41	63	149

Table 5: Other Intramural Performance Measures deemed Important to the Agency – Veterinary Services

		FY16	FY17	FY18	FY19	FY20
	New Confidentiality Agreements	0	17	3	29	35

	New Material Transfer Agreements	16	17	35	44	37
	New Material Transfer Research Agreements	0	5	0	0	6
	Peer-Reviewed Scientific Publications	46	33	22	56	74
	Non-Indexed Publications	0	0	0	0	0

2.4.4. Success Stories Demonstrating Downstream Outcomes From Technology Transfer Activities

APHIS-VS transfers technology to State and international animal health agencies, animal owners, animal industry, and domestic and international universities via a variety of methods, including collaborations. Recent examples include:

- VS participated in a workshop entitled: "Obstacles to Vaccination: A Look Forward, at the Wageningen University and Research in Lelystad, Netherlands on October 17, 2019. The workshop brought together industry, academia, and veterinary biologics regulators for presentations on hurdles to vaccination and potential opportunities for solutions. VS staff presented on the VS policy and guidance for platform technology and prescription platform technology, and then participated in a panel discussion.

- VS participated in the International Cooperation on Harmonization of Technical Requirements for Registration of Veterinary Medicinal Products (VICH) 38th Steering Committee Meeting & 12th VICH Outreach Forum Meeting in Tokyo, Japan on November 18-21, 2019. VICH is an

international harmonization effort principally between the United States, Japan, and the European Union (EU). Several other countries, such as Canada, New Zealand, Australia, and South Africa, are official observer countries, and also adopt VICH guidelines that serve as standardized methods across the various regions. VS serves as part of the U.S. delegation representing the USDA before the VICH Steering Committee on issues related to veterinary biologics.

- VS presented a webinar on December 18, 2019, to discuss poultry health and vaccine licensing to the poultry industry. Topics on the agenda included: the background of CVB and the Virus-Serum-Toxin Act; autogenous products; immortalization of isolates; new vaccine registration for emerging or re-emerging pathogens; pullorum antigen labeling, vaccine production and shipping; product availability; and technology platform changes.

- VS attended a meeting, on January 22-23, 2020, at FAO Headquarters in Rome, Italy. The meeting was aimed at improving security of vaccine supply against FMD and other similar transboundary diseases.

- VS spoke during the Animal Health committee meeting portion of the 2020 American Sheep Industry Annual Conference, held in Paradise Valley, Arizona, on January 23, 2020, to an audience of sheep and goat producers and the sheep and goat biologics industry and answered questions they had regarding availability of biologics that producers need to protect the health of their sheep and goats.

- VS attended the America Veterinary Medical Association Council on Biologics and Therapeutic Agents and Clinical Practitioners Advisory Committee meeting on February 5-6, 2020. The agenda included information on current/emerging biologics and therapeutic issues.

- VS presented at a Quantitative Polymerase Chain Reaction (PCR) Seminar held at Iowa State University the weeks of February 10 and February 17, 2020. Several topics were presented in the lecture titled *An Introduction to PCR, Real-Time PCR, Experimental Design, Analysis, and Troubleshooting*. This lecture was part of a seminar containing several individually tailored lectures for both beginners and experienced laboratory workers. Some topics discussed were Primer Design, Real-time PCR, PCR and qPCR Troubleshooting.

- VS met with Canadian Centre for Veterinary Biologics staff members on May 29, 2020, to discuss many topics including updates, strategies, and general communications data.

- VS attended the Association of Veterinary Biologics Companies (AVBC) Spring Meeting on June 18, 2020. AVBC hosted their annual spring meeting via Zoom. Representatives from VS attended the open session and additional staff members provided updates to on-going VS initiatives.

- VS provided, via a virtual format, four seminars on PCR, the week of August 31, 2020. Approximately 30-40 representatives from 12 manufacturing firms (licensees and permittees) attended each seminar and each seminar was approximately an hour in length.

- VS representatives participated in the Animal Health Institute (AHI) Spring and Fall meetings**,** on June 24 – 25, 2020 and September 30 - October 1, respectively. These meetings were held via Zoom. VS representatives meet with AHI members in several working group sessions, as well as participated in the meeting's General Session in providing updates on current projects and initiatives within VS. Additionally, VS members met with the Veterinary Biologics Section Steering Committee to provide insight into current initiatives and further collaborative discussion between industry and VS.

- VS personnel participated in three Emergency Validation Exercises during September 2020. The exercise scenarios gave representatives from the NAHLN laboratories, NAHLN program office, and the Reference Laboratory the opportunity to practice the Emergency Validation Process, which can be used to validate a new sample type after a foreign animal disease detection or outbreak. The exercise scenarios choices were based on virulent ND, African swine fever (ASF), or FMD and focused on the Emergency Validation process.

- VS personnel collaborated with the National Animal Disease Center Infectious Bacterial Diseases research unit and the Centers for Disease Control and Prevention (CDC) Epidemic Intelligence Service, on a project in the U.S. Virgin Islands (USVI) to investigate the role of mongoose as a reservoir of leptospirosis. The collaboration produced the first isolations of pathogenic leptospires from mongoose in the USVI. Due to the success of that investigation, the study will now focus on rodent reservoirs. NVSL will receive approximately 200 samples for isolation and screening by fluorescent antibody and PCR. This project will allow NVSL to

further compare the various diagnostic methods.

- VS personnel initiated a monthly Journal Club for the Foreign Animal Disease Diagnostic Laboratory (FADDL) Oak Ridge Institute for Science and Education fellows, providing an opportunity for each fellow to explore an area of interest, present the article and respond to questions from more established FADDL Scientists. The Journal Club has expanded in scope to include lectures from FADDL subject-matter experts on topics including foreign animal diseases, FMD vaccine production, and Ebola outbreak response. The meeting is now hosted as a weekly seminar series with a growing list of participants including scientists from all FADDL Sections including Diagnostic Services, Reagent and Vaccine Services, Scientific Liaison Services, Proficiency and Validation Services, the NAFMDVB, and the NAVVCB.

- VS personnel engaged in detailed meetings to validate the equipment lists for the new NBAF, including utility needs and confirmation of final placement of the equipment throughout the laboratory, with the support of a company specialized in laboratory fit-out. Participation included members from all FADDL's sections. VS personnel collaborated with the Canadian Food Inspection Agency (CFIA) and the Australian Animal Health Laboratory (AAHL), to develop, evaluate, and validate a novel multiplex qPCR diagnostic assay to improve current molecular diagnosis of brucellosis. Additionally, serological tests using the Brucella-unique antigens identified through current work by AAHL will be developed and evaluated.

- VS personnel attended the EU Reference Laboratory for Fish and Crustacean Diseases

Compendium on Diagnostic Techniques for Viral Fish Diseases, serving as an external advisor for the first virtual offering of this annual course. The focus of the training course was on methods for implementation of surveillance procedures for EU and OIE listed fish diseases. Topics covered included legislative basis for fish health management and animal health law in the EU, sampling procedures for surveying listed fish disease, the use of cell culture for surveying for fish diseases, in addition to molecular methods and bioinformatics utilized to identify and detect listed fish diseases.

- VS personnel collaborated with ARS personnel at Washington State University as part of a USDA Grand Challenge project proposal. An overarching goal of this proposal is to develop an improved diagnostic assay to detect cattle infected with Babesia bovis and B. bigemina. The current focus is whole genome sequencing of Babesia isolates grown in vitro that originate from cattle in Mexico. This pilot study will be used to develop the workflow for future submissions to NVSL as part of the Grand Challenge, as well as provide a reference sequence for both B. bovis and B. bigemina that future work will build upon. A number of co-authored publications are expected to be an outcome of this work.

- To assist with the workforce development needs for the transition to NBAF, the APHIS NBAF Scientist Training Program will provide support to qualified applicants for laboratory-based graduate training in foreign animal diseases, including FMD, classical swine fever, ASF, and Japanese encephalitis. Individuals complete research in collaboration with university scientists, as well as subject-matter experts at PIADC and the CFIA. We currently have 21 students

enrolled from 12 universities. APHIS will announce applications for fall of 2021 in early summer 2021.

- The VS-led inaugural NBAF Laboratorian Training Program (NLTP) was held June-July 2020. The NLTP is a technical training program held in collaboration with the Kansas State University Biosecurity Research Institute. A total of 10 current undergraduates or recent graduates from Kansas and Missouri participated in the training.

- VS personnel participated in the National Animal Health Monitoring System 2019 Goat Study which ran from July 1 through December 2019. Approximately 4,700 goat producers from 25 of the major goat-producing States also participated. An important aspect of this study was conduct genotyping for scrapie resistance. NVSL received, extracted, sequenced, and analyzed approximately 6,200 samples in support of this study.

- VS personnel in the NAHLN Program Office collaborated, through APHIS One Health, with the CDC to support the animal component of Coronavirus Disease – 2019 (COVID-19) Household Transmission Study. The CDC study of positive households includes sampling over a 14-day period from residences in Wisconsin and Utah. Animal samples from both the Wisconsin and Utah studies will be sent to the University of Wisconsin Veterinary Diagnostic Laboratory, a member of the NAHLN, with presumptive positives being tested at NVSL for confirmation.

- VS personnel presented a talk on testing considerations for Severe Acute Respiratory Syndrome

Coronavirus 2 (SARS-CoV-2) in animals on the 2020 Zoonoses and One Health Updates call to an audience of 500 participants including veterinarians, physicians, nurses, epidemiologists, and others who work on One Health issues at the human-animal-environment interface. Additionally, the call was recorded for Continuing Education and is available at https://www.cdc.gov/onehealth/zohu/2020/may.html.

- VS personnel conducted an FMD Laboratory Response Tabletop Exercise focused on the response efforts of PIADC and its coordination with the NAHLN Program Office and one State laboratory. Participants gained a better understanding of outbreak collaborations as they responded to a small-scale U.S.-based FMD outbreak scenario.

- VS personnel with the NAHLN participated in a virtual inaugural Tactical Sciences Coordination Network Meeting. The meeting, funded through a grant from NIFA, is aimed at identifying gaps and solutions in protecting biosecurity.

- VS personnel presented an overview of Equine Import Testing Overview at two Strategy and Policy-hosted gatherings of equine industry representatives. The presentations focused on the details of each testing protocol and test interpretation for the three main diseases of interest: piroplasmosis, dourine, and glanders. At one of the meetings, 5years of data was presented, demonstrating a non-negative testing rate across more than 30,000 imported horses of less than 0.02 percent, addressing a long-standing industry concern regarding high false-positive rates.

- VS entered into an interagency agreement with ARS Meat Animal Research Center (USMARC) in Clay Center, Nebraska, to exchange scientific materials and expertise regarding Salmonella isolates. USMARC will provide Salmonella isolates not otherwise available to NVSL for use in validation studies of NVSL's new CRISPR/STAMP assay. In return, NVSL will provide Salmonella isolates from a recent antimicrobial resistance study to USMARC for use to validate a newly developed assay for determining Salmonella pathogenicity level.

- VS personnel collaborated with representatives from the Panama national laboratory, a Panamanian animal health official, and four OIE representatives regarding how Panama can set up its own equine encephalitis testing program, especially for Eastern equine encephalitis and Venezuelan equine encephalitis. This meeting served as a starting point for a productive relationship in which NVSL experts can assist in setting up Panama's equine encephalitic testing and secure samples for NVSL's use in validation activities. Additionally, NVSL experts will be providing training on test methods and processes to the Panama laboratory.

- VS personnel participated in and presented at a webinar hosted by the NAHLN Exercises and Drills Working Group to share experiences and lessons learned by NAHLN laboratories responding to the COVID-19 pandemic. Information shared included working with a Clinical Laboratory Improvement Amendments (CLIA) laboratory director, emergency use authorizations, human testing versus animal testing, CLIA certification strategies, daily operations, testing and age distribution data, results reporting, emergency hiring practices, reshuffling personnel, maintaining services, and partnering with a high complexity laboratory

without State public health involvement.

- VS personnel have been actively engaged in collaborations with four Central American countries (Costa Rica, Guatemala, Honduras, and El Salvador) to develop plans to characterize zoonotic tuberculosis, enhance laboratory capacity, and train officials on sample collection and skin testing. These collaborations have led to three signed agreements with one pending.

- VS personnel collaborated with the CDC, multiple State agencies in Utah, and APHIS Wildlife Services to collect samples from SARS-CoV-2 affected milk farms and around them. NVSL received over 700 samples for SARS-CoV-2 testing so far and expects to receive several hundred more samples. NVSL has also received about 60 samples from mink on which to perform bacterial culture to determine if there are secondary causes of mortality as a result of SARS-CoV-2.

- VS personnel participated in the Regionalization Evaluation for the Notice of Determination of the highly pathogenic avian influenza (HPAI) and ND Status of Romania, which was published with an effective date of August 26, 2020. Based on this evaluation, APHIS concluded that Romania meets the requirements to form part of the European Union Poultry Trade Region, a region of the European Union recognized by APHIS that meets APHIS requirements for being considered low risk of HPAI and ND, and for which the importation of live birds and poultry and poultry meat and products is harmonized.

2.5. WILDLIFE SERVICES

2.5.1. Mission Statement

The mission of USDA APHIS Wildlife Services (WS) is to provide Federal leadership and expertise to resolve wildlife conflicts to allow people and wildlife to coexist. Wildlife is an important public resource greatly valued by the American people. However, wildlife is a dynamic and mobile resource that can damage agricultural and industrial resources, pose risks to human health and safety, and affect other natural resources. The WS program carries out the Federal responsibility for helping to solve problems that occur when human activity and wildlife are in conflict with one another. The WS program strives to develop and use wildlife damage management strategies that are biologically sound, environmentally safe, and socially acceptable.

2.5.2. Nature and Structure of Research Program

WS conducts program delivery through its regional and State offices and national programs, providing high-quality wildlife damage management services for its customers that result in the protection of agriculture, wildlife and other natural resources, property, and human health and safety. The National Wildlife Research Center (NWRC) is the research branch of Wildlife Services. NWRC is the only Federal Laboratory devoted to resolving problems caused by the wild animals.

NWRC is headquartered on the Foothills Campus of Colorado State University in Fort Collins, CO. The NWRC employs more than 150 scientists, technicians, and support personnel at its Fort Collins, CO, headquarters and at the 7 field stations located throughout the United States. Five field stations are co-located with universities (University of Florida, Oregon State University, Utah State University, North Dakota State University, and Mississippi State University). The range of geographic locations facilitates a unique ability to address regional wildlife damage management issues. Further, NWRC routinely conducts international consultations in this specialized area.

Scientists at NWRC apply a diverse array of expertise to the development of practical, biologically, environmentally, and socially sound methods to resolve these problems and to maintain the quality of the environment shared with wildlife. Scientific staff specializes in several disciplines, including animal behavior/psychology, chemistry, biology, ecology, zoology, economics, genetics, immunology, pharmacology/toxicology, physiology, wildlife biology, and wildlife disease. In addition, NWRC works with other experts who have additional specialties through cooperative ties with universities, not-for-profit research facilities, and other public and private research entities.

NWRC works within three general focus areas: Damage Management, Conservation, Public and Animal Health. NWRC develops effective wildlife damage management methods through contributions in the following areas:

- Damage assessment

- Investigation of the biology and behavior of problem animals
- Evaluation of the impact of management practices on wildlife and the environment
- Development and improvement of existing management technologies
- Investigation of potential applications of new management technologies
- Support for registration of chemicals, drugs, and devices used to manage wildlife
- Transfer of scientific and technical information
- Provision of scientific guidelines on wildlife damage for use by regulatory agencies
- Development of cooperative research and training with other organizations
- Responsiveness to needs of user groups and the public

Regardless of the method being developed by NWRC scientists, work is guided by a specific set of criteria to ensure that products and techniques will be accepted and adopted by industry and the public. That set of criteria includes striving towards tools and techniques that are as selective for the problem species as possible, are considered socially responsible, present as little environmental impact when

employed, are cost effective and, when appropriate, receive appropriate regulatory oversight prior to release and during use.

In addition to this general set of criteria for each product development exercise, the NWRC also works under a ”pipeline” workflow paradigm, originating with ideas from WS scientific and operational staff, or outside entities culminating with a useful tool and/or technique. A key step in this pipeline is locating private or university partners to assist with product development efforts, ultimately taking the technology to a marketable product. Partnering can take a variety of forms including formal developmental technology transfer agreements through patenting and licensing.

2.5.3. WS Technology Transfer Goals, Objectives, and Measures of Success

WS follows the general USDA definition of technology transfer as the adoption of research outcomes (i.e., solutions) for public benefit. Through public and private partnerships, NWRC research creates 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. Technology transfer is critical to accelerating use of public research and methods development, creating economic activity, jobs, and sustaining economic development.

WS uses formal instruments of technology transfer, including Confidentiality Agreements (CA), Material Transfer Agreements (MTA), Material Transfer Research Agreements (MTRA), and Cooperative Research and Development Agreements (CRADA). In addition, WS transfers technology through patents and invention licenses for commercialization by the private sector. WS has an ongoing formal agreement with USDA Forest Service's Technology Transfer office (USFS) to assist with the preparation of Intellectual Property Agreements and Patents. Licensing NWRC patented intellectual property is arranged through USDA ARS Office of Technology Transfer (ARS OTT). NWRC's Technology Transfer Program Manager serves as the primary liaison for APHIS to the FS and ARS OTT.

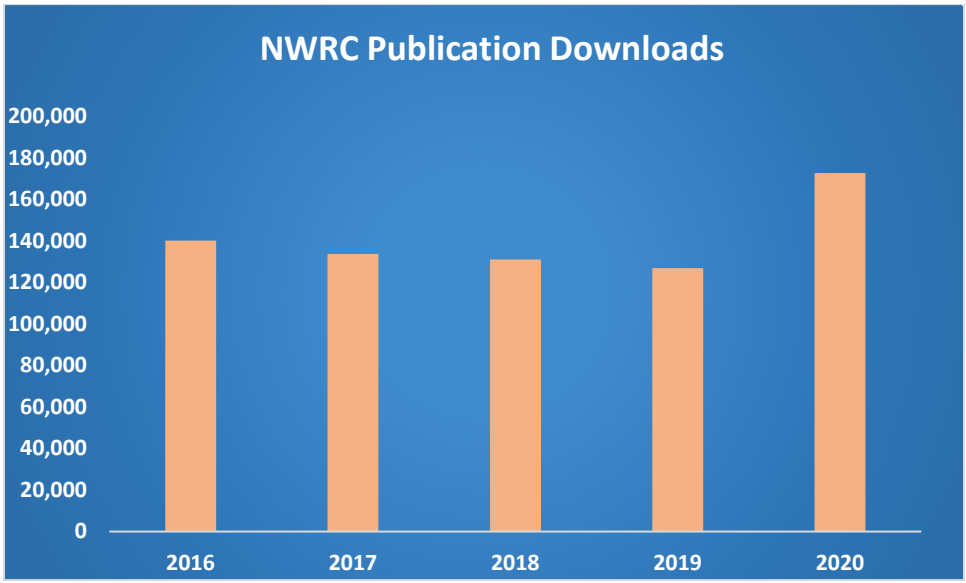
In addition to patents and licenses, WS transfers knowledge and technology through many other formal and informal mechanisms. Primary among these methods for NWRC scientists is publication in peer-reviewed scientific journals. Other important mechanisms for transferring technology and knowledge include presentations at technical or professional conferences and publications in proceedings, technical assistance to the public or stakeholders, informal and formal exchange of information and products among colleagues, public outreach via factsheets, brochures, web pages, and social media and laboratory open houses.

WS scientific and operational staff have dedicated staff devoted to registration/authorization of products with regulatory agencies, including the Environmental Protection Agency's Office of Pesticide Programs, the Food and Drug Administration's Center for Veterinary Medicine, and the USDA Center for Veterinary Biologics. As products are developed, they proceed through the research and development pipeline and registration process with the appropriate regulatory agencies (see schematic below). Products with limited private market potential, but are highly desirable to WS mission operations, are produced and distributed by the WS Pocatello Supply Depot. Products with significant private market potential are licensed for sale to a private company. Efforts to increase the number of APHIS products licensed by private companies include patenting innovative technology, development of CRADAs and Material Transfer Research Agreements, participating in regional technology development functions, actively participating with the national and Mid-Continent region of the Federal Laboratory Consortium, interacting directly with national, State and local governments, universities, and industries, and enhancing training for NWRC scientists in technology transfer.

NWRC currently measures success of its technology transfer efforts using several metrics. The most basic metric of any research organization is their publication success. In FY20, NWRC scientist published 105 peer-reviewed manuscripts and 18 trade non-indexed publications or book chapters. Even more impressive though is the rate at which publications have been downloaded by external audiences, especially NWRC that only employs 30 scientists in positions where publication is required. Since NWRC began tracking publication downloads in 2006, annual downloads have steadily increased each year as internet capabilities were built out. In 2020, NWRC publications were downloaded 172,695

times. This represents a significant increase over the 4-year average of 132,980. Between 2016 and 2020, NWRC publications were downloaded 704,616 times.

Downloads of NWRC publications between 2016 and 2020.



Another measure of the NWRC's technology transfer and research development efforts is the number of individual organizations our scientists and support staff collaborate with annually. On average, NWRC partners or otherwise collaborate with approximately 150 individual institutions, an impressive number given the size of the Center's research staff. The majority of collaborations were with universities, but State and local governments and private partners were highly represented. NWRC scientists and staff collaborate with over 20 foreign governments or institutions annually.

As stated above, NWRC also enters into technology transfer agreements (CAs, MTAs, MTRAs, and CRADAs), cooperative agreements, cooperative service agreements, grants and memoranda of understanding with collaborators. NWRC tracks the number (the specifics of which are reported in the Combined Metrics Tables below) and monetary value of all types of agreements. Efforts to increase the amount of cooperator funding continue to be a priority.

Cooperator funding, both incoming and outgoing, is another important means of developing and transferring NWRC technology to universities and private collaborators. In 2020, NWRC entered into a total of 85 agreements (see table below). Incoming cooperator funding at NWRC averages about 15 percent of the annual budget and has remained steady during the last 5 years: $2.7 million in 2016, 2017, and 2018, $2.3 million in 2019, and $3.1 million in 2020.

FY2020 NWRC Agreement Financials

Type	#	Total
Cooperative Agreements	43	$ 3,530,843.04
Cooperative Service Agreements	8	$ 533,015.88
CRADA	2	$ 257,163.21
Interagency Agreements		
Incoming Funding	10	$ 2,629,411.88
Outgoing Funding	2	$ 100,611.03
Material Transfer Research Agreements	15	$ 10,000.00
Grants	2	$ 663,340.00
TOTALS	85	$ 7,724,385.04
Total Incoming Funding		$ 3,162,427.76
Total Outgoing Funding		$ 4,561,957.28

2.5.4. Metric Tables

Table 1: Disclosures and Patenting – Wildlife Services						
		FY16	FY17	FY18	FY19	FY20
1	Invention Disclosures Received	3	4	4	6	3
2	Total Patent Applications Filed	4	5	0	5	5
3	US	4	5	0	5	4
4	Foreign	0	0	0	0	1
5	Total PCT Applications Filed	0	2	0	0	0
6	Total Patents Issued	3	1	1	3	4
7	US	3	1	1	1	2
8	Foreign	0	0	0	2	2

Table 2: Licenses – Wildlife Services						
		FY16	FY17	FY18	FY19	FY20
8	Invention Licenses, Total Active	3	3	3	3	3
9	New Invention Licenses	0	0	0	0	0
10	New Invention Licenses Granted to Small Businesses	0	0	0	0	0
11	Income Bearing Licenses, Total Active	3	3	3	3	3
12	New Income Bearing Licenses	0	0	0	0	0
13	Exclusive, Total Active	0	0	0	0	0
14	Partially Exclusive, Total Active	0	0	0	0	0
15	Non-Exclusive, Total Active	0	0	0	0	0
16	Other Licenses, Total Active	0	0	0	0	0

17	New Other Licenses	0	0	0	0	0
18	New Other Licenses Granted to Small Businesses	0	0	0	0	0
	Elapsed Amount of Time for Granting Invention Licenses					
19	Average (months)	ND	ND	ND	ND	ND
20	Minimum (months)	ND	ND	ND	ND	ND
21	Maximum (months)	ND	ND	ND	ND	ND
22	Licenses Terminated for Cause	ND	ND	ND	ND	ND

Table 3: Income from Licensing – Wildlife Services

		FY16	FY17	FY18	FY19	FY20
22	Invention License Income	$5,037	$25	$158	$140	$100
24	Other License Income	0	0	0	0	0
25	Total Earned Royalty Income	$5,037	$25	$158	$140	$100
26	ERI from Top 1% of Licenses	$5,037	$25	$158	$140	$100
27	ERI from Top 5% of Licenses	$5,037	$25	$158	$140	$100
28	ERI from Top 20% of Licenses	$5,037	$25	$158	$140	$100
29	Minimum ERI	$37	$25	$158	$240	$100
30	Maximum ERI	$5,000	$25	$158	$240	$100
31	Median ERI	ND	ND	ND	ND	ND

	Disposition of ERI					
32	Percentage Distributed to Inventors	49	100	100	100	100
33	Percentage Distributed to Lab/Agency	51	0	0	0	0

Table 4: Collaborative Agreements – Wildlife Services

		FY16	FY17	FY18	FY19	FY20
34	Total Active Cooperative Research and Development Agreements (CRADAs)	9	6	7	9	11
35	New CRADAs	2	0	1	3	3
36	New CRADAs Involving Small Businesses	2	0	1	3	1
37	Other Collaborative Agreements	321	185	154	71	85

Table 5: Other Intramural Performance Measures Deemed Important to the Agency – Wildlife Services

		FY16	FY17	FY18	FY19	FY20
	New Confidentiality Agreements	7	5	9	8	10
	New Material Transfer Agreements	17	7	12	9	12
	New Material Transfer Research Agreements	7	6	15	13	7
	Peer-Reviewed Scientific Publications	99	108	175	122	105
	Non-Indexed Publications	8	20	23	11	18

2.5.5. Success Stories Demonstrating Downstream Outcomes From Technology Transfer Activities

Feral Swine Management Tool Development

Invasive feral swine have been reported in at least 35 States in the United States. Their population is estimated at over 6 million. The NWRC Feral Swine Research Project (FSRP) is participating in multiple partnerships that are leading to significant advances in toxicant and toxicant delivery systems and machine learning for use in feral swine damage management. In addition, scientists in this group have received national recognition for authoring seminal publications on feral swine damage management issues.

In FY20, the FSRP partnered with private business in two separate CRADAs aimed at developing new tools for feral swine management. The first CRADA, which began several years ago, is with an Australian vertebrate pesticide manufacturing company. It focuses on the development and registration of a toxicant for use in feral swine management. The 9-year effort has resulted in two toxicant formulations. The first formulation is registered for use in Australia and is seeing promising results and sales. The second formulation is in late-stage field trials in the United States and is expected to be submitted for a U.S. pesticide registration in calendar year 2022. The Australian company is looking to establish U.S.-based manufacturing capabilities by either constructing a new manufacturing facility or contracting with an existing U.S. pesticide manufacturer. This collaboration also resulted in a patent-pending, swine-specific feeding station that prevents most other wildlife from accessing bait.

The second FSRP CRADA is with a U.S. company and focuses on the development of a recognition system to identify feral swine as they approach a feeding station. This CRADA uses two unique recognition systems, acoustic and visual, to distinguish feral swine from other species, such as deer, bear, or raccoon. When a positive identification is made, a mechanism on the feeding station is unlocked allowing the pig to access the bait. The combination of the toxicant, feral swine feeder and feral swine recognition system will yield valuable new tools for feral swine management.

In another collaboration, FSRP worked with computer scientists from a western university to develop software that analyzes images from motion-activated cameras (also known as camera traps or trail cameras) which remotely observe wildlife, including feral swine. Trail cameras can produce thousands of images which must be individually inspected to determine if the species of interest is in a photo. Machine learning was used to quickly and accurately review and classify images. NWRC and APHIS' Veterinary Services, as well as State, non-profit, and university partners, used more than 3 million known wildlife images to train and test a deep-learning model to classify species of wildlife captured on camera traps. The trained model classified approximately 2,000 images per minute and achieved 98-percent accuracy in identifying U.S. wildlife species, the highest accuracy of such a model to date. The free tool, available as an R package (Machine Learning for Wildlife Image Classification), allows users to either use the existing trained model, or train their own model using images of wildlife from their studies. This system speeds up the analysis and evaluation of the types of wildlife attracted to and accessing the bait stations, which aids in the bait station design.

In recognition of their expertise and leadership in the field of feral swine damage management, FSRP scientists were finalists for the FY 2020 APHIS Scientist of the Year Award. They were acknowledged for their contributions to the development of "Invasive Wild Pigs: Ecology, Impacts and Management, a comprehensive, 480-page reference book on invasive feral swine. Nominees were judged on the following criteria: scientific impact, scientific collaborative spirit, fostering an exceptional scientific work environment, supporting science in APHIS' mission, and external scientific recognition. The book was also named The Wildlife Society's 2020 Wildlife Publication of the Year in the Edited Book Category.

Vehicle-based Lighting System To Reduce Deer-Vehicle Collisions

Published estimates suggest there are more than 1.5 million deer-vehicle collisions each year in the United States, resulting in more than 100 human deaths, thousands of personal injuries, and $1 billion in vehicle damages. To reduce deer-vehicle collisions during low-light conditions, NWRC researchers built upon methods and findings from their previous work involving animal responses to approaching vehicles and various lighting effects. Unlike prior efforts, however, this methodology included a rear-facing light-emitting diode (LED) light bar which illuminated a larger portion of the vehicle's front surface than standard headlights alone.

In a series of experiments with free-roaming white-tailed deer, researchers found the likelihood of dangerous deer-vehicle interactions decreased from 35 percent to only 10 percent of vehicle approaches when using a rear-facing light bar plus headlights versus just headlights alone. The reduction in

dangerous interactions appeared to be driven by fewer instances of immobility or “freezing” behavior by deer when the light bar was used. The new lighting system takes advantage of a deer’s predator avoidance behavior (also known as flight behavior). Light reflected from the front surface of the vehicle provides a more reliable looming image to deer, thus encouraging the deer to move out of the path of the approaching vehicle. When an object “looms,” it is perceived by the animal as becoming increasingly larger, helping the animal realize that the object is approaching versus one that is stationary.

The patent-pending methodology (U.S. Patent Application No. 16/668,253) can be developed as an after-market device, like a brush guard or bumper, or can be embedded in the vehicle as part of the manufacturing process. WS is currently seeking licensing partners for this technology.

Developing Genetic Tools for the Future

While invasive species eradication successes have occurred on islands using traditional removal methods, such as toxicants, these approaches are costly and time-consuming. Their use can be limited due to concerns associated with secondary hazards to people, domestic animals, and nontarget species. Emerging tools, such as genome editing, holds promise as a future tool for invasive species management.

Genome editing to produce engineered gene drives promotes the inheritance of a particular gene to increase its prevalence in a population. During normal sexual reproduction, each of the two versions of a given gene (also known as alleles) has a 50-percent chance of being inherited by offspring (Mendelian

inheritance). Gene drives are genetic systems that circumvent these traditional rules. They greatly increase the odds that one specific version of a gene will be passed on to offspring. Thus, gene drives could be used to change a population into a single sex population or could promote a particular gene that causes the demise of a population. Gene drives occur naturally, but the idea of engineering them for disease and invasive species management first came about over the last several decades. Gene drive technologies designed to eliminate a specific population provide an alternative approach for invasive species management, but the potential for drive-bearing individuals to escape from target release areas and impact populations elsewhere is a major concern for conservationists and managers.

As part of a multi-agency collaboration, Genetic Biocontrol of Invasive Rodents (GBIRd), NWRC geneticists investigated a novel gene drive approach ("locally fixed alleles") for potential use in managing invasive species populations. The approach assumes that rodent populations on small islands experience genetic drift that leads to their alleles becoming "fixed" (i.e., identical). In contrast, rodents that exist in larger populations on the mainland maintain more diverse alleles. North Carolina State University researchers in collaboration with NWRC used mathematical models of island mouse populations to explore the feasibility of this approach and the degree to which localization can be achieved. Model simulations showed that if a mouse bearing a gene drive associated with a locally fixed allele were to escape to a neighboring mainland mouse population in which the target allele was not fixed but still present, the mainland mouse population would experience a small degree of population suppression. Eventually, the much larger and diverse mainland population would rebound from any impacts. The comparatively large size of the mainland mouse population with its diverse alleles would prevent the gene drive from spreading effectively.

2.5.6. Economic Impact Studies

Sophie McKee, Aaron Anderson, Keith Carlisle, Stephanie A. Shwiff. 2020. Economic estimates of invasive wild pig damage to crops in 12 U.S. States Crop Protection. 132:105105. DOI: 101016/j.cropro.2020.105105

We report the results of a survey on invasive wild pig (*Sus scrofa* L.) damage and control in 12 U.S. States (Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, and Texas). The crops chosen for this study represent the "second tier" in terms of economic importance after the six crops that were the subject of Anderson et al. (2016). The survey was distributed by the USDA National Agricultural Statistics Service (NASS) in the summer of 2019 to a sample of producers in each of the States (except California) of the following six crops: hay, pecans (*Carya illinoinensis* (Wangenh.) K. Koch), melons (cantaloupe (*Cucumis melo* L. var. *cantalupensis*), honeydew (*Cucumis melo* L. (*Inodorus* Group)), and watermelon (*Citrullus* Schrad.), sugarcane (*Saccharum officinarum* L.), sweet potatoes (*Ipomoea batatas* (L.) Lam.), and cotton (*Gossypium* L.). In California, where there the crops of economic importance differed from the other States in the study, damages were calculated for producers of hay, almonds (*Prunus dulcis* (Mill.) D.A. Webb), grapes (*Vitis vinifera* L.), sod, carrots (*Daucus* L.), lettuce (*Lactuca* L.), and strawberries (*Fragaria* L.). In total, 7,438 respondents completed the questionnaire. Findings indicate that damage can be substantial. The highest yield loss estimates occurred for hay in Texas. Control efforts were common, but no control method was rated by the majority of producers as very effective. Extrapolating crop damage estimates to the State-level in 12 States with reportable damage yielded an

estimated crop loss of $272 million/yr. Though large, this number likely represents only a small fraction of the total damage by wild pigs in these States because it only includes crop damage to six crops. We hope findings from this survey will help guide control efforts and research, as well as serve as a benchmark against which the effectiveness of future control efforts can be measured.

Jordan C. Navin and Aaron M. Anderson. 2020. Wildlife strike cost revelation in the US domestic airline industry. Transportation Research Part D: Transport and Environment. 78:102204. ***DOI:*** **10.1007/s10530-020-02311-8**

The aim of this study is to provide a general overview of the economic impacts associated with vertebrate invasive species (VIS) in the United States and suggests a methodology for differentiating types of damage. We identify a general framework for categorizing VIS damage that separates this damage into three main categories: destruction, depredation, and disease. We then examine how this framework fits into current published estimates of damage and management costs. Economic impacts associated with feral swine damage and management are plentiful enough to warrant separate treatment from other VIS and are observed in all three categories. For all VIS examined in this study, damage estimates associated with destruction provide the most evaluations of VIS impacts, especially destruction of crops. Evaluations of the losses associated with depredation are largely absent from the literature. We find that while published studies have estimated substantial economic impact associated with VIS, the current state of the literature focusing on VIS frequently fails to address all of the categories of damage, is difficult to compare or replicate, and is unsuited for extrapolation to nation-wide estimates of damage.

Stephanie Shwiff, Alex Pelham, Steven Shwiff, William Haden-Chomphosy, Bienna R. Brown, Karina Ernst, Aaron Anderson. 2020. Framework for assessing vertebrate invasive species damage: The case of feral swine in the United States. Biological Invasions. 22(10):3101-3117. DOI: 10.1007/s10530-020-02311-8

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3. Agricultural Research Service (ARS)

3.1. Mission Statement

ARS delivers scientific solutions to national and global agricultural challenges.

3.2. Nature and Structure of Research Program

ARS is the largest intramural scientific research agency of the U.S. Department of Agriculture (USDA). Agency goals are to find solutions to agricultural problems that affect Americans every day, from field to table, such as (a) protecting crops and livestock from pests and diseases, (b) improving the quality and safety of agricultural products, (c) determining the best nutrition for people from infancy to old age, (d) sustaining our soil and other natural resources, (e) ensuring profitability for farmers and processors, (f) keeping costs down for consumers, and (g) supporting the growth and development of rural America.

In fiscal year (FY) 2020, ARS employed approximately 2,000 scientists and postdoctoral researchers, and approximately 6,000 other employees to conduct 690 research projects at more than 90 locations. Research projects were organized within 1 of 15 national programs (see table). The Office of National Programs (ONP) in Beltsville, Maryland, plans the scope and objectives of the Agency's research projects, and five area directors implement research projects at the locations in their geographic areas.

ARS research program management, showing 16 national programs

Animal Production and Protection	Natural Resources and Sustainable Agricultural Systems	Crop Production and Protection	Nutrition, Food Safety, and Quality
Food Animal Production	Water Availability and Watershed Management	Plant Genetic Resources, Genomics and Genetic Improvement	Human Nutrition
Animal Health	Soil and Air	Crop Production	Food Safety (animal and plant products)
Veterinary, Medical, and Urban Entomology	Grass, Forage, and Rangeland Agroecosystems	Plant Diseases	Quality and Utilization of Agricultural Products
Aquaculture	Sustainable Agricultural Systems Research	Crop Protection and Quarantine	

ARS conducts a series of reviews designed to ensure the relevance and quality of its research work and maintain the highest possible standards for its scientists. Customer input helps keep the research focused on the needs of the American food and agricultural system. Plans for each active research project undergo a thorough, independent external prospective peer review managed by the Office of Scientific Quality Review. All ARS employees, including the scientific workforce, are subject to annual performance reviews, and all research scientists and engineers have technology transfer as a performance element in their annual performance appraisal. Research scientists undergo a rigorous peer review Research Position Evaluation System on a 3- to 5-year cycle. These processes ensure the continuing high-quality output of the ARS research addressing the needs of U.S. agriculture.

3.3. ARS Approach and Plans for Conducting Technology Transfer

Because of the delegations of authority by the Secretary of Agriculture, the ARS Office of Technology Transfer (OTT) is assigned the responsibility for obtaining patent protection for intellectual property (IP), developing strategic partnerships with outside organizations, licensing USDA technologies to the private sector and academia, and performing other activities that effectively transfer ARS research outcomes and technologies to the marketplace. USDA's Office of the General Counsel provides legal guidance to OTT on IP matters as needed.

The ARS technology transfer program has centralized policy and approval procedures that are managed by OTT. Research agreement negotiation and implementation is decentralized and managed by the ARS area offices. Area office technology transfer staff members serve as liaisons with scientists, ARS managers, OTT, university partners, and the private sector.

To facilitate technology transfer, OTT is organized into three sections. The Partnership and Administration Section conducts day-to-day operations, coordinates technology transfer policy development, interacts with ONP on agreement policy and review, and coordinates the activities between the partnership, patenting, and licensing sections. This section maintains strong stakeholder relationships at local, regional, and national levels, ensuring the adoption of research results. This section is also responsible for coordinating, managing, and reviewing agreements, and overseeing and managing the Agricultural Research Partnerships (ARP) Network. The Patent Section of OTT provides strategic guidance to scientists regarding patent protection for their research results. The section is also responsible for receiving invention reports; convening three national patent committees (Mechanical and Measurement, Life Sciences, and Chemistry), and a Plant Protection Committee; preparing and

prosecuting patent applications; and reviewing patent legal work performed by a cooperator and an ARS contract law firm. The Licensing Section of OTT manages invention licensing from all the intramural scientists in every USDA agency, including the review of license applications, negotiation of licenses, and monitoring of license agreements to assure compliance. This section also collects and disburses license revenues, manages international patent filings, and provides expert advice on all matters related to USDA invention licensing.

At ARS, technology transfer is accomplished through many mechanisms, such as:

- Developing written information for customers and stakeholders, including scientific publications, publications in trade journals, and reports to stakeholders;
- Releasing plant germplasm to the public;
- Transferring research materials to scientists outside of ARS;
- Entering into formal partnership agreements, such as Cooperative Research and Development Agreements (CRADAs) and other cooperative agreements;
- Licensing IP (patents, Plant Variety Protection certificates, and biological materials); and
- Participating in meetings with industry organizations and universities; workshops and field days;

and distributing information to the public via the ARS Office of Communications, the National Agricultural Library, and other sources.

Because the ARS mission is to transfer technologies for broad public use by the most effective mechanism, ARS pursues patents and licensing principally to incentivize commercialization and to facilitate technology transfer to the marketplace. This is usually the case when complementary investment by the private sector is necessary to commercialize a product and patent protection is required to protect this investment. By ARS policy, patents are not filed on inventions that are considered to be only research tools. The purpose of this policy is to encourage scientific research. Judicious use of intellectual property rights (IPR) is an important cornerstone of the patent committees. IPR is used as an incentive for commercialization and full realization of the research impact of USDA technologies. In licensing practices, ARS continues to reserve the right to allow use of any IP-protected technology for research purposes (non-commercial).

OTT devised and enhanced a two-way communication mechanism between technology transfer professionals (both at OTT and area offices), ONP, and scientists in the field through the use of technology transfer strategy calls after each patent decision and each Innovation Fund round. In FY 2020, more than 140 strategy sessions were conducted to devise customized technology transfer strategies to ensure adoption of research outcomes of each project. This was featured in the Best Practice Spotlight of Technology Transfer Tactics, a monthly newsletter, in March 2018.

Meaningful performance metrics in technology transfer are often difficult to formulate. ARS has defined

better metrics for technology transfer within USDA. For example, successful outcomes for ARS may include improved agricultural practices, gathering and compilation of scientific information that enhances U.S. competitiveness, increased awareness about pathogens to help prevent human and animal diseases, or findings that help corporations and universities make informed decisions in allocating their research resources. Many of these outcomes do not require patenting or subsequent licensing for implementation.

Licensing policies also promote small business success with reasonable licensing fees in the early years and annual maintenance fees and royalties that escalate in subsequent years, sometimes after the first commercial sale of the product. Licensing further enhances commercialization by encouraging the broadest utilization of a Federal invention. ARS also incentivizes scientists on the reporting of inventions, patenting, and licensing by providing 25 percent of the license revenues to inventors (this is higher than the 15 percent required by statute). Thus, policies are in place that incentivize commercialization, minimize transaction costs, and provide fair and equitable compensation for those who create Federal innovations.

OTT founded the Agricultural Research Partnership (ARP) Network to expand the impact of ARS research by enhancing the likelihood that these outcomes will be adopted. Although replete with scientific expertise, the ARS research program does not have the resources or the authority to provide ARS commercial partners with business mentoring, marketing, manufacturing, and fiscal resources needed for the success of their businesses. Consequently, the ARP Network was established to provide these complementary assets. By combining ARS research expertise with complementary capabilities and

talents of partnering organizations, the ARP Network stimulates economic growth through technological advancements.

OTT collaborated with USDA's National Institute of Food and Agriculture (NIFA) to create the Small Business Innovation Research -Technology Transfer (SBIR-TT) Program. SBIR-TT encourages small businesses to collaborate with ARS researchers and/or license ARS technologies and submit an SBIR application. The relevant language in the SBIR Request for Applications states, "Additional factors that will be considered in the review process include whether an application involves a CRADA with a USDA laboratory, or a license to a USDA technology."

3.4. Technology Transfer Highlights

- In FY 2020, there were 107 active CRADAs, 28 of which were newly executed. The 28 new CRADAs contributed $1,242,717 directly to ARS research projects, and approximately 68 percent of them are with small businesses. There were 323 active Material Transfer Research Agreements (MTRAs), 106 of which were newly executed. The 106 new MTRAs contributed $1,575,241 directly to ARS research projects (see Table 1 in Section 3.5 and Figures 1 and 2 in Section 3.9).

- In FY 2020, 188 new invention disclosures were received; 76 patent applications were filed; and 40 utility patents, 3 plant patents, and 7 Plant Variety Protection Certificates were obtained. Although the year in which a patent is issued is not typically the year in which the patent

application is filed, over time the ratio of patents issued over the number of patent applications filed is an indicator of "judicious" patenting. Over the last 5 years, this indicator suggests that approximately 65 percent of the patent applications result in an issued patent (see Table 2 in Section 3.5 and Figures 3, 4, and 5 in Section 3.9).

- In FY 2020, 93 new licenses were executed (80 percent with small businesses and 7 percent with universities). The total number of active licenses has steadily increased over the last 5 years from 419 to 565. Fifty-six percent of the income-bearing licenses were granted exclusively. The total income from all active licenses was more than $3.24 million. Although the year that a license is signed is not typically the year the patent is issued, over time the ratio of newly signed licenses over the number of newly issued patents is an indicator of "judicious" patenting, considering the commercial viability of the technology and other factors. Over the last 4 years, this indicator suggests that approximately 45 percent of the issued patents have been licensed (see Tables 3 and 4 in Section 3.5 and Figures 6, 7, 8, and 9 in Section 3.9).

- OTT reviewed and executed licenses for the Animal and Plant Health Inspection Service (APHIS) and the Forest Service.

- OTT worked with Federal Laboratory Consortium (FLC), NIFA, the National Institute of Health, U.S. Department of Energy, National Aeronautics and Space Administration, Small Business Administration, Center for Innovative Food Technology, and the University of Maryland Smith

School of Business to design strategies to enhance ARS technology transfer and economic development.

- OTT redesigned its website with new pages and content. The new website is more user friendly and should attract more businesses and other entities to work with ARS.

- OTT held in-person technology transfer training with 53 scientists at 6 locations in 5 States. The COVID-19 pandemic prevented additional in-person training, which required OTT to develop a virtual form of the training. More than 900 people attend the first virtual training webinar.

- OTT worked with the USDA Media and Broadcast Center to create a video explaining technology transfer and highlight ARS technology transfer successes to replace static technology transfer display cases.

- OTT worked with FLC on the Airport/Mass Transit addition to LabTech in Your Life. LabTech in Your Life- House is a virtual environment where visitors can explore the familiar setting of a home and discover successfully commercialized Federal technologies that are now commonly used household items. ARS developed 17 technologies used throughout the house. LabTech in Your Life- Airport/Mass Transit will highlight five outcomes of ARS research: Hydrangea cultivars, turfgrass cultivars, fruit and vegetable snacks, fruit and vegetable sandwich wraps, and 100-percent fruit bars.

- OTT employees served as moderators/speakers/trainers in broad technology transfer activities and forums, including the FLC national and regional meetings.

- OTT received 99 Innovation Fund applications, of which 37 were funded. The Innovation Fund, from licensing revenue, provides ARS scientists up to $25,000 on a competitive basis for a given project per year. The purpose of the fund is move ARS research outcomes closer to adoption by industry, academia, and other stakeholders. The first 50 projects have resulted in 5 patent applications and 2 Plant Variety Protection applications; 10 licenses; 12 publications and 1 factsheet; 4 workshops and 1 public website; and 23 university and industry collaborations.

- OTT created a LinkedIn group for the ARP Network. Through FY 2020, membership grew from 250 to more than 530. In FY 2020, there were 32 LinkedIn posts by OTT. Posts included highlighting a research topic area with an overview of the past and present ARS research program in that area, followed by a posting of technologies available for licensing in that area. In addition, other noteworthy items were posted, such as ARS news, research partnership opportunities, USDA videos on various research projects, and Federal business resources. Most posts received more than 300 views.

- OTT served on the Inter-Agency Working Group on Technology Transfer, led the Return-on-Investment Group on Private Sector Engagement, and represented USDA on the Lab to Market subcommittee of the National Science and Technology Council's Committee on Technology. OTT took the lead on the Metrics Strategic Group to establish meaningful ways in which to

quantify the outcomes of Federal research and development enterprise. OTT published two peer-reviewed papers: (1) M. Bahar and R. J. Griesbach, 2020. Cultivating and Nurturing A Culture of Innovation in Federal Agencies. *les Nouvelles*, September 2020, pg. 185-190, and (2) M. Bahar and R. J. Griesbach, 2020. Agricultural Extension: The Precursor to Today's Technology Transfer. *les Nouvelles*, September 2020, pg. 232-236.

3.5. Metric Tables

TABLE 1. Collaborative relationships for research and development					
	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Total number of active CRADAs[1]	219	249	189	193	147
Active CRADAs with small businesses	70	62	73	120	64
Total number of newly executed CRADAs	39	57	51	56	28
Newly executed CRADAs with small businesses	12	17	31	38	19
Total funds to be received	$2,113,880	$2,804,160	$3,121,739	$3,280,189	$1,242,717
Total number of active MTRAs[2]	288	432	354	292	323
Active MTRAs with small businesses	ND	ND	ND	ND	ND
Total number of newly executed MTRAs	89	101	118	100	106
Newly executed MTRAs with small businesses	ND	ND	ND	ND	ND
Total funds to be received	$373,953	$743,603	$2,267,886[4]	$637,636	$1,575.241
Total number of active other agreements[3]	3,230	4,108	3,215	1,888	1,987
Newly executed other agreements	756	876	621	951	1,210
Number of newly executed MTAs	823	664	645	614	423
Newly executed outgoing MTAs	539	445	476	398	266
Total number of publications[4]					
Peer-reviewed scientific journal	4,473	4,467	4,138	3,816	3,933
Trade journal	65	66	68	48	30
Meeting abstracts	1,178	1,022	855	612	615

ND, data not available.
[1] Cooperative Research and Development Agreement
[2] Material Transfer Research Agreements. Involves collaborative research on a specific material.
[3] Includes Trust Fund Cooperative Agreements, Reimbursable Agreements, Interagency Agreements, and Non-Funded Cooperative Agreements.
[4] Number of published manuscripts.

TABLE 2. Invention disclosures and patenting					
	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Total new invention disclosures[1]	174	169	306	228	188
University co-owned	58	27	29	39	24
Non-university co-owned	29	21	16	18	13
USDA solely owned	87	121	261	171	47
Scientific discipline:					
Biological materials	19	8	141	86	46
Life science	73	72	55	47	35
Chemical	48	43	32	42	31
Mechanical & measurement	21	28	20	13	16
Plant patents[2]	5	5	6	2	4
Plant variety protection[2]	8	13	11	4	4
Plant breeder's rights[2]	0	0	0	1	0
Plant public release	28	44	41	33	52
Based upon CRADA research	25	22	23	14	11
Total U.S. patent applications filed[3]	92	109	108	85	76
University co-owned	10	21	31	17	20
Non-university co-owned	9	23	25	17	20
USDA solely owned	73	65	52	51	31
Scientific discipline:					
Life science	50	45	53	29	22
Chemical	24	38	30	34	40
Mechanical & measurement	10	7	14	12	8
Plant patents	6	11	3	4	1
Plant variety protection	2	8	8	6	5
Total U.S. patents issued[3]	53	68	61	65	50
University co-owned	15	22	19	16	12
Non-university co-owned	12	19	11	21	9
USDA solely owned	26	27	31	28	22
Scientific discipline:					
Life science	23	37	29	33	17
Chemical	13	13	15	17	17
Mechanical & measurement	9	6	12	4	6
Plant patents	5	6	2	8	3
Plant variety protection	3	6	3	3	7
Foreign patenting					

Total foreign patent applications filed	ND	ND	ND	ND	60
Total PCT Applications Filed	ND	ND	ND	ND	16
Total foreign patents issued	ND	ND	ND	ND	3

ND, data not available.
[1] Inventions arising at a Federal laboratory. For FY 2014, also includes the plants protected through Plant Variety Protection.
[2] In the United States, plants may be protected in one of two ways based upon their mode of reproduction: patent (vegetatively reproduced) through the USPTO or variety protection (seed reproduced) through USDA, Agricultural Marketing Service. International plants are protected through plant breeder's rights.
[3] Includes U.S. patent applications, divisional applications, continuation-in-part applications, provisional applications, Plant Variety Protection, and Patent Cooperation Treaty (PCT).

TABLE 3. Profile of active licenses

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Total active licenses[1]	419	426	460	497	565
Executed to small businesses[2]	150	155	161	180	236
Executed to universities	187	186	199	201	208
Amended in FY	4	4	8	4	4
Invention licenses[4]	348	351	374	377	393
Executed to small businesses	112	114	113	114	121
Executed to start-up businesses	6	6	6	6	6
Executed to universities	178	176	189	188	191
Other IP Licenses[5]	71	75	86	120	172
Executed to small business	38	41	48	66	115
Executed to start-up businesses	0	0	0	0	0
Executed to universities	9	10	10	13	17
Total newly executed licenses	29	38	40	51	93
Executed to small businesses	9	19	12	25	74
Executed to start-up businesses	0	0	0	0	0
Executed to universities	14	9	12	10	7
Invention licenses	23	29	27	17	30
Executed to small businesses	6	13	3	7	15
Executed to start-up businesses	0	0	0	0	0
Executed to universities	14	8	12	7	3
Other IP Licenses	6	9	13	34	63
Executed to small businesses	3	6	9	18	59
Executed to start-up businesses	0	0	0	0	0
Executed to universities	0	1	0	3	4
Total income-bearing licenses	418	425	459	496	564

Exclusive	289	293	312	312	316
Partially exclusive	9	6	7	7	7
Non-exclusive	120	126	140	177	241
Invention licenses[6]	347	350	373	376	392
Exclusive	280	283	302	299	300
Partially exclusive	9	6	7	7	7
Non-exclusive	58	61	64	70	85
Other IP licenses[7]	71	75	86	120	172
Exclusive	9	10	10	13	16
Partially exclusive	0	0	0	0	0
Non-exclusive	62	65	76	107	156
Total royalty-bearing licenses	145	129	134	125	109
Invention licenses	123	107	112	105	96
Other IP licenses	22	22	22	20	13
Elapsed Amount of Time for Granting Invention Licenses					
Average (months)	4.9	6.1	6.3	5.9	3.6
Median (months)	3.7	5.1	5.5	5.0	2.6
Minimum (months)	0.9	1.3	0.9	1.8	0.8
Maximum (months)	16.0	13.7	24.1	34.9	15.8
Licenses terminated for cause	0	0	0	0	0

ND, data not available.
[1] The rest of the licenses were to medium or large size businesses.
[2] A small business, together with its affiliates, must not have more than 500 employees.
[3] For the purpose of this report, a startup company is a privately held, U.S. for-profit company operating for less than 5 years and actively seeking financing to commercialize a Federal scientific work product.
[4] Invention licenses refer to patents and Plant Variety Protection certifications.
[5] Other intellectual property (IP) licenses refer to biological materials licenses.
[6] Invention licenses refer to patents and plant variety protection certificates.
[7] Other IP licenses refer to biological materials licenses.

TABLE 4. Income from licensing					
	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Total income all active licenses	$4,784,466	$5,713,803	$3,799,170[5]	$3,553,446	$3,243,196
Invention licenses[2]	$4,456,054	$5,377,909	$3,490,236	$3,272,205	$2,968,437
Other IP licenses[3]	$328,412	$325,566	$308,934	$281,241	$274,759
Total Earned royalty income (ERI)	$3,633,239	$3,503,866	$2,715,861	$3,171,355	$2,678,083
Median ERI	$3,966	$3,698	$3,056	$3,154	$4,221
Minimum ERI	$5	$15	$21	$ 0.75	$13
Maximum ERI	$818,537	$769,167	$265,844	$573,545	$279,915
ERI from top 1% of licenses[4]	NP	NP	NP	NP	NP
ERI from top 5% of licenses	$1,811,637	$1,639,557	$1,218,975	$1,579,185	$1,111,917
ERI from top 20% of licenses	$3,043,395	$2,933,342	$2,227,058	$2,655,368	$2,210,427
ERI distributed					
Percentage Distributed to Inventors	25	25	25	25	25
Percentage Distributed to Lab/Agency	0	0	0	0	0
Innovation Fund[5]	ND	$483,814	$618,000	$833,500	$898,144

ND, data not available; NP, data not presented; ERI, earned royalty income.
[1] Two of the top revenue-generating licenses expired in FY 2017.
[2] Invention licenses refer to patents and Plant Variety Protection certifications.
[3] Other IP licenses. Refer to biological materials licenses.
[4] Not presented, represents one license.
[5] Funds are from previous year's revenue.

3.6. Downstream Outcomes

NUTRITION, FOOD SAFETY, AND QUALITY

National Programs:

- **Human Nutrition, NP 107**
- **Food Safety, NP 108**
- **Quality and Utilization of Agricultural Products, NP 306**

Dietary carbohydrate intake contributes to reduced stress. Mental stress is linked to risk of chronic diseases. In an 8-week randomized controlled trial that compared effects of a healthy Dietary Guidelines for Americans (DGA)-based diet against the less healthy typical American diet, ARS scientists in Davis, CA, found that the DGA diet, with a higher amount of dietary carbohydrate, resulted in reduced concentrations of a key stress response hormone, cortisol, and dampened stress-induced cortisol reactions. These novel findings provide new evidence suggesting that in the context of a healthy diet, carbohydrate consumption may provide some protection from stress-related disease risk. Furthermore, this apparent stress and cortisol dampening effect could reduce stress-related eating by some individuals

and improve their ability to sustain a healthier diet based on the DGA. (NP107, C3, PS3A, Project No. 2023-51530-022-00D)

Obesity dampens immune responses in young women to levels similar to those of elderly. Both obesity and aging are associated with muted immune and inflammatory responses. Limited knowledge, however, exists on differences in the immune system between young and older adults with obesity. ARS-supported scientists in Boston, MA, conducted a study to compare circulating indicators of immunity in young and older women with obesity. Twenty-three young (age 23–43) and 21 older (age 60–83) women with obesity participated. Older women with obesity had significantly fewer circulating immune cells of four specific types than young women. With few exceptions, there was no significant difference in inflammation markers or stimulated lymphocyte proliferation and cytokine production by peripheral blood mononuclear cells between young and older participants. These findings contrast with those previously reported in young and older subjects with healthy weight and call for further investigation into the impact of obesity on premature aging of the immune system. (NP107, C3, PS3B, Project No. 8050-51000-100-00D)

Healthy gut microbes increase muscle strength in the elderly. ARS-funded researchers in Boston, MA, compared the gut microbiome composition in 18 older adults in good physical condition with that of 11 older adults in poor physical condition and observed differences in both sets of individuals. Researchers transferred fecal samples from humans into the guts of microbiome-free mice and found the mice that received transplants from the people in good physical condition had significantly greater muscle strength than mice that received fecal transplants from the people who were in poor physical

condition. These results suggest that a role exists between the gut microbiome and maintenance of muscle strength with advancing age. Such understanding may lead to advances in mobility and independence for older adults. (NP107, C3, PS3A, Project No. 8050-51000-104-00D)

Intestinal permeability is affected by gender and genetics in children. A certain amount of absorption by the intestine is essential for life but excess permeability is associated with adverse health consequences. ARS-supported researchers in Houston, TX, studied large numbers of children with normal gastrointestinal function, irritable bowel syndrome (IBS), or functional abdominal pain (FAP), along with their siblings and parents. Several partially absorbable sugar derivatives were administered orally, and amounts recovered in urine over a day measured intestinal permeability. As expected, children with IBS had increased intestinal permeability, but this was not found in those with FAP. Boys had a significantly weaker intestinal barrier than girls and both the siblings and parents of children with higher permeability showed the same pattern of results. Because recent studies show that bacteria in the intestine contribute to liver disease and perhaps obesity, the stronger the gut barrier, the less likely those microorganisms and their potentially harmful products can enter the bloodstream. These data may help explain why boys are more susceptible than girls to liver disease. (NP107, C4, PS4A, Project No. 3092-51000-062-00D)

Diet is a risk factor for type 2 diabetes (T2D) and T2D may impact bone health. Dietary guidance seldom distinguishes between subgroups of individuals, but increasing evidence is showing that a one-size-fits-all approach to diet recommendations is not valid. ARS scientists in Boston, MA, in conjunction with scientists at the Harvard Medical School and the Beth Israel Deaconess Medical Center

assessed bone health in Black and White individuals with no diabetes, prediabetes, and early stage T2D. Association between bone health and blood sugar control differed by race. There was no change across the diabetic categories among White individuals; however, bone health was significantly lower in Black subjects with T2D than in those with prediabetes or no diabetes. These findings suggest there may be different associations of blood sugar and bone health in Black and White subpopulations and that health/diet guidance for the population in general may not be adequate for some subpopulations. (NP107, C3, PS3A, Project No. 8050-51000-099-00D)

Non-inherited changes in DNA due to diet are associated with cardiovascular disease risk factors and all-cause mortality. Although genetics is known to play a role in heart disease and expected lifespan, there are also changes to genetic material that are not inherited. Such changes include binding of methyl groups to DNA, which changes the expression, or activity, of various genes. ARS-supported scientists in both Boston, MA, and Houston, TX, took part in a consortium that analyzed blood samples from 6,662 individuals with European ancestry, 2,702 with African ancestry, and 360 with Hispanic ancestry. In individuals with European ancestry, habitual diet quality was associated with differential methylation levels in sites on DNA of white blood cells, most of which were also associated with multiple health outcomes. These findings demonstrate that integrative genomic analysis of dietary information may reveal molecular targets for disease prevention and treatment that are amenable to improved dietary choices. (NP107, C5, PS5B, Projects Nos. 8050-51000-103-00D and 3092-51000-063-00D)

Neonatal diet alters gut bacteria and metabolite signals in infants. Early nutrition can significantly affect intestinal colonization by normal bacteria and modulate host health through a series of bacterial metabolites that interact with cells of the body. ARS-supported scientists in Little Rock, AR, analyzed fecal samples from infants in an effort to describe the bacteria and their metabolites over the course of the first year of life in babies who were exclusively fed breastmilk or formula. Breastfeeding resulted in increased abundance of bacteria that produce short-chain fatty acids and metabolites that serve as signals in development of the gut and other organs. In addition, bacterial metabolites such as kynurenic acid, which helps optimize immune responses, including inhibiting allergy, were higher in breastfed infants. These results provide new information about how breastfeeding promotes intestinal and immune health in infants and adds to the scientific basis for the recommendation by the Centers for Disease Control and Prevention that infants should be breastfed. (NP107, C5, PS5A, Project No. 6026-51000-012-00D)

Maternal diet and body fat alter placental DNA methylation. Epigenetic changes, or changes in gene expression rather than alterations of the genetic code itself, provide a possible explanation of how the *in utero* environment programs health throughout the life course. Epigenetic marks can include addition or removal of natural chemicals such as methyl groups on the DNA or the proteins (histones) around which DNA is wrapped. Researchers in Little Rock, AR, compared DNA methylation in placentas from 150 women who were either normal weight or overweight/obese. Both maternal weight status and dietary saturated fat intake were associated with epigenetic changes in placental DNA and many of the modified genes related to fat synthesis, insulin signaling pathways, and DNA packaging. These data indicate that improved diet and weight status can modify placental function and development of the fetus. (NP107, C5, PS5B, Project No. 6026-51000-012-00D)

Data linked across multiple domains are critical for solving problems related to diet and human health. Building bridges between unconnected human nutrition databases is a critical first step to solving these problems, but manually mapping items between databases is expensive and time consuming. The food composition database that underlies the Automated Self-Administered 24-Hour (ASA24) dietary assessment tool includes 65 nutrients; however, linking this database to other similar databases could provide estimates for nearly 100 additional nutrients. ARS scientists in Davis, CA, and collaborators at the University of California, Davis, used machine learning and database mapping methods to estimate the dietary intake of lactose, which existed only in the unconnected database. Food items in the two databases were acceptably matched based on their nutrient profiles and text descriptions. Compared to manual mapping of food items by experts, this method reduced the time required for estimating lactose by 99.7 percent. These results suggest that unconnected food composition databases may be linked using computer-assisted methods, thereby expanding the ability of researchers to assess many additional nutrients not available in single databases. This increased capacity benefits the nutrition research community by expanding the tools they have available for their studies, and will also benefit nutrition professionals, and eventually consumers, by improving dietary guidance for Americans. (NP107, C2, PS2A, Project No. 2032-51530-026-00D)

National survey data and related databases for recent years are available. ARS has partnered with the Centers for Disease Control and Prevention on producing dietary data from the National Health and Nutrition Examination Survey (NHANES) for many years. ARS scientists in Beltsville, MD, released nationally representative survey data for 2017–2018 as part of What We Eat in America, NHANES. In addition, the 2017–2018 update of the Food and Nutrient Database for Dietary Studies was released.

Tables providing national dietary intake estimates compared to nutrient requirements were also made public. Additionally, seven dietary data briefs were published providing information for nutrition policy and education on topics such as intake of added sugars; vegetable, fruit, and dairy intake; late evening snacking; and convenience stores as sources of foods and nutrients. Regular updates of nationally representative data are essential for the Federal Government to produce dietary guidance, including the Dietary Guidelines for Americans, which is published jointly by USDA and Health and Human Services (HHS). (NP107, C2, PS2B, Project No. 8040-53000-020-00D)

Daily zinc supplementation affects immune function in Laotian children at risk of deficiency. Zinc deficiency, common among children in Southeast Asia, impairs immune function and increases the risk of infectious disease. ARS scientists in Davis, CA, worked with collaborators from the University of California, Davis, Khon Kaen University in Thailand, and Lao Tropical and Public Health Institute in Lao People's Democratic Republic, to determine how the method of supplementation affected immune function in rural Laotian children. Children (age 6–23 months) received one of four zinc treatments (placebo, daily zinc, daily zinc with other micronutrients, or only when children were treated for diarrhea) for 9 months. The results of the study showed that daily zinc tablets resulted in significant improvement in immune endpoints relative to the placebo group. Immune cell concentrations in blood decreased in children who received zinc supplements, suggesting that zinc may have helped control an underlying infection. These results provide important information for public health experts in Laos and internationally regarding how best to supplement zinc to prevent deficiency. (NP107, C3 PS3A, Project No. 2032-51530-026-00D)

First ever expert advice to parents and caregivers on healthy eating behaviors in young children. Researchers know that to prevent childhood obesity, how children eat may be as important as what they eat. In addition, we know that the first 5 years of life are a critical period for helping children learn how to regulate their food intake to match their energy needs. ARS-supported researchers in Houston, TX, led a partnership with other scientific experts and the American Heart Association to release their first ever scientific statement giving advice on how to foster healthy eating behaviors in children under 5 years of age. This guidance will broadly reach parents and caregivers across the country and provide strategies for healthy eating behaviors with the goal of reducing childhood obesity. (NP107, C4, PS4A, Project No. 3092-51000-063-00D)

Fruit pigment metabolites cross the blood-brain barrier. The blood-brain barrier is a special feature of the circulatory system that protects the brain from many factors circulating in the blood. There has been much speculation about whether potentially health-promoting dietary compounds can cross the barrier to reach the brain and improve mental performance. ARS scientists in Beltsville, MD, collaborated with colleagues in several European universities to show for the first time that flavanols, which are abundant in fruits, cocoa, and pulses, are metabolized by the intestinal bacteria to a form that is absorbed and circulates in the blood that can be recovered from brain tissue. The results of a series of studies using rats and pigs clearly demonstrate the permeability of the blood-brain barrier and provide additional evidence that a gut-brain axis exists and that there are potential health benefits from eating a variety of plant foods. (NP107, C3, PS3A, Project No. 8040-51530-058-00D)

Eating enough protein at every meal decreases odds of functional disability. Functional ability is associated with quality of life, health, and mortality. Given our rapidly growing aging population, preserving functional ability is a public health priority. Strategic intake of dietary protein has demonstrated promise for preventing functional disability during aging. ARS scientists in Grand Forks, ND, in collaboration with scientists at North Dakota State University, found an association in a large epidemiologic study that eating at least 1 gram of protein for every kilogram of body weight daily and distributing the protein evenly across all eating occasions decreased the odds for functional disability by up to 61 percent, and the greater the number of eating occasions containing enough protein, the stronger the benefit. The study involved 8,000 people who were at least 60 years old. Results suggest that consuming protein and spreading it across all meals is associated with better physical functioning in older adult patients. (NP107, C3, PS3B, Project No. 3062-51000-057-00D)

High intake of plant pigments is associated with reduced risk of Alzheimer's disease. Alzheimer's disease is the cause of 60 to 80 percent of dementia cases, making it a major public health challenge for which there is no effective therapy. ARS-supported researchers in Boston, MA, followed 2,809 men and women older than age 50 for an average of 20 years as part of the Framingham Heart Study. Specific fruits and vegetables rich in plant compounds known as flavonoids and associated with significantly reduced risk of Alzheimer's dementia included blueberries, strawberries, and red wine. Apples, pears, oranges, bananas, and tea also showed some beneficial associations. These results suggest that adding certain fruits to the diet may be linked to a reduced risk for the most widespread type of senility and support the recommendation of the Dietary Guidelines for Americans to eat a variety of fruits and vegetables. (NP107, C3 and 5, PS3B and 5A, Project No. 8050-51530-014-00D)

People with certain genes are more likely to gain weight when consuming sugar-sweetened beverages. Consuming sugary drinks is associated with obesity and obesity-related diseases, but the biological mechanism that connects sugar-sweetened beverage intake to obesity is not completely understood. ARS researchers in Boston, MA, examined the relationship of biochemical compounds found in the blood of participants in the Boston Puerto Rican Health Study as it related to their intake of sugar-sweetened beverages and body mass index. The scientists identified 28 compounds, many of them implicated in fatty liver, that linked sugar-sweetened beverage intake with obesity. Those compounds were mainly in two genetic pathways of lipid metabolism. These findings suggest that drinking sugar-sweetened beverages disrupts the metabolism and leads to an increased risk of obesity in persons with specific versions of genes. Reducing consumption of sugar-sweetened beverages would contribute to reducing the risks of obesity and fatty liver disease that currently affect millions of Americans. (NP107, C4, PS4A, Project No. 8050-51000-107-00D)

A mega-method to analyze contaminants in foods. Analysis of foods for the presence of pesticides, veterinary drugs, and environmental contaminants is necessary for public health. In 2003, ARS developed the QuEChERS approach to sample analyze pesticide residues in foods. This method has now become the primary and gold standard used worldwide in chemical residue analysis. Instrumentation and technology have continued to improve in the past 17 years, creating a need to update the QuEChERS method. Consequently, ARS scientists in Wyndmoor, PA, have now developed and validated the “quick, easy, cheap, effective, rugged, safe, efficient, and robust” (QuEChERSER) mega-method using mass spectrometry to analyze pesticides, veterinary drugs, and environmental contaminants in foods. So far, the new QuEChERSER mega-method has been validated for up to 349 diverse analytes in fish, bovine,

caprine, and ovine muscle; hemp products; and fruits and vegetables. Once implemented internationally, QuEChERSER is expected to eventually supplant QuEChERS as the primary method for monitoring a wide array of chemical contaminants in foods. (NP108, C1, PS4, Project No. 8072-42000-080-00D)

Colistin-resistance in U.S. animal-origin food. Colistin, also known as polymyxin E, is a last-resort antibiotic against drug-resistant Gram-negative bacterial infections. Recently, a mobile colistin resistance gene, mcr-1, was discovered in clinical and animal samples. The prevalence of mcr-1-mediated colistin resistance has never been investigated in U.S. animal products. To fill this gap, ARS researchers in Albany, CA, screened more than 5,000 domestic food samples (chicken rinse, ground beef, beef trim, poultry, raw pork, and catfish) randomly collected by the USDA, Food Safety and Inspection Service for the presence of mcr-1 using a novel method developed by ARS that combines an enzyme-linked immunosorbent assay with real-time polymerase chain reaction methods. The screening data revealed a very low prevalence (0.02 percent) of the mcr-1 gene in tested samples. Subsequent whole genome sequence analysis on the single positive isolate revealed that the mcr-1 gene resided on an IncI2 plasmid. This study was the first systemic and large-scale investigation of mobile colistin resistance in U.S. food animal products, and the information will be important for trade-related food safety risk assessments. (NP108, C1, PS3, Project No. 2030-42000-049-00D)

A novel strategy for estimating *Salmonella* contamination levels in raw ground beef. *Salmonella* is a leading cause of foodborne illness worldwide. In spite of the use of numerous process controls in food production industries, there has been little progress in decreasing the occurrence of *Salmonella* food poisoning over the past decade. This is in part because current testing methods indicate only the

presence or absence of *Salmonella*, but they do not measure how much contamination is in a tested product. To address this need, ARS scientists in Clay Center, NE, developed a novel strategy for rapidly estimating *Salmonella* contamination levels in raw ground beef based in the same amount of time that it takes to detect *Salmonella* in enrichments using two different commercial molecular detection methods. The ability to detect high levels of *Salmonella* contamination will enable meat companies to improve their process controls and remove more highly contaminated products from the food chain. This will improve the safety of beef and decrease the incidence of human exposure to levels of *Salmonella* that cause disease. (NP108, C1, PS3, Project No. 3040-42000-017-00D0)

Predictive models to identify antifungal compounds. Antifungal chemicals are often used to reduce crop spoilage and reduce the occurrence of mycotoxins. However, safer, better antifungal agents are needed. Some potential antifungal agents are phenolic compounds that have many uses due to their consumer-friendly properties. To aid in the selection of better antifungal compounds, ARS scientists in Peoria, IL, applied computational artificial intelligence and machine learning methods to develop mathematical models that identified chemical properties of phenolic compounds that reduce contamination by mycotoxin-producing fungi. Two of the antifungal compounds evaluated, thymol and carvacrol, are components of essential oils of many plants, including the popular culinary herb thyme. These models will help toxicologists, microbiologists, and chemists discover better antifungal agents to benefit the food industry. (NP108, C1, PS6, Project No. 5010-42000-049-00D)

Survival of bacterial pathogens in manure-amended soils. Fresh produce, especially leafy greens, has been implicated as a source of several major outbreaks of foodborne illness in the United States.

Manure-amended soils continue to represent a potential source of bacterial pathogen contamination. The Food and Drug Administration (FDA) Produce Safety Rule, as part of the Food Safety Modernization Act, prohibits the use of untreated manure within 90 or 120 days prior to the harvest of edible produce crops. To examine the role of manure types in produce contamination, ARS scientists in Beltsville, MD, in collaboration with the FDA and academia, collected manure/produce data from 12 field trials conducted over 4 years at 3 separate locations. The data were used to identify factors affecting the survival of *Escherichia coli* in manure-amended soils. The studies showed that poultry litter supported longer survival of *E. coli* than dairy or horse manure. Days of rainfall and soil moisture content affected *E. coli* survival in manure-amended soils. These results assisted the FDA in developing models to determine the appropriate interval between application of raw manure and harvest of edible crops to minimize fresh produce contamination, thus making produce safer for consumers (NP108, C1, PS6, Project No. 8042-32420-006-00D)

Safe use of chlorine dioxide to sanitize produce and eggs. Chlorine dioxide (ClO2) gas is very effective at eliminating microbiological contaminants from a variety of fruits, vegetables, melons, seeds, and even eggs. Although the gas has been proposed for sanitizing human foods to eliminate pathogens and rot organisms, it has not been approved by the Food and Drug Administration or the Environmental Protection Agency for use on foods other than tomatoes and cantaloupe. This non-approval is because chemical residues of ClO2 have not been described. ARS researchers in Fargo, ND, demonstrated that nearly all the residue deposited on the surfaces of eggs, avocados, onion, and sweet potato after the use of ClO2 for sanitation is a harmless chloride ion. The studies also found that chlorate, a byproduct of ClO2, was present in low quantities and could serve as a useful marker of ClO2-treated products. The

results show that chemical residues are not a major obstacle for the commercial development of cost-effective ClO2 gas technologies to safely eliminate pathogens and rot organisms from a variety of produce and eggs. (NP108, C1, PS4, Project No. 3060-32420-001-00D)

Combining cold plasma and hydrogen peroxide as a postharvest intervention. Fresh fruits and vegetables are a major source of essential nutrients for humans. However, these products are subject to contamination by both pathogens and spoilage microorganisms, which reduces their safety, quality, and nutritional value. Fresh produce is often consumed raw or after minimal processing, and pathogen contamination can present higher risks of outbreaks of foodborne illness. Because there are food safety uncertainties along the supply chain, postharvest treatments are essential in reducing the risk of pathogen contamination and minimizing the risk of microbial spoilage. ARS scientists in Wyndmoor, PA, combined cold plasma and hydrogen peroxide aerosols to produce highly reactive radicals that reduced the populations of bacteria on fresh fruits. Applying cold plasma to hydrogen peroxide increased the effectiveness of hydrogen peroxide aerosols and killed almost 100 percent of Salmonella and Listeria on surfaces of apples, cantaloupe, and tomatoes. This new process did not affect appearance, color, texture, or nutritional quality of the produce. The outcome of this work has a direct application to the produce industry, and ARS is collaborating with industry partners to evaluate the commercial implementation of the new intervention technology. (NP108, C1, PS3, Project No. 8072-41000-101-00D)

A novel aqueous ozone intervention against *Escherichia coli* O157:H7 on fresh beef. Ozone is a naturally occurring water-soluble gas that is an effective germicide and has been approved as a sanitizer

for food-contact surfaces and food products. *E. coli* O157:H7 is a foodborne bacterial pathogen that has been implicated in many cases of meat-associated human illness in the United States. The last step in beef processing is to rapidly cool the carcass to 35°F, and this is accelerated by applying periodic sprays of cold water. ARS scientists in Clay Center, NE, evaluated a new nanobubble technology that creates a stable, high concentration of aqueous ozone for its effect on pathogenic *E. coli* that can be present on beef during spray chilling. The results indicated that the novel ozone spray was 80 percent more effective in reducing pathogenic *E. coli* than water alone. Because beef carcasses are usually chilled under recurring sprays of water for 6–8 hours, by adding ozone this process can now be a continued antimicrobial step leading to safer end products for consumers. (NP108, C1, PS5, Project No. 3040-42000-018-00D)

A rapid test for masked toxins in wheat. Trichothecenes are a group of fungal toxins (mycotoxins) that can contaminate oat, wheat, barley, and corn, and cause substantial economic losses worldwide. Trichothecenes are toxic to humans and animals, and upon consumption, the toxin inhibits ribosomal protein, DNA, and RNA synthesis; mitochondrial functions; and cell division while simultaneously activating a cellular stress response. As part of efforts to improve monitoring of these trichothecene toxins, ARS scientists in Peoria, IL, in collaboration with the Institute of Sciences of Food Production in Bari, Italy, developed a new method to detect trichothecenes in wheat. Trichothecenes are also toxic to plants, but plants can protect themselves from the toxins by attaching a sugar residue to a trichothecene molecule, which makes them less toxic. The plant toxin derivatives are called masked mycotoxins, and are difficult to detect. During the human digestion process, the original toxin may be released from the masked state, resulting in mycotoxin poisoning. The new toxin/masked mycotoxin detection method is

rapid, sensitive, and convenient and will be used to monitor trichothecenes and their modified forms in wheat. Improved monitoring for the trichothecenes and their masked forms can be used to reduce exposure to these toxins by diverting the contaminated food product from the food supply. (NP108, C1, PS6, Project No. 5010-42000-049-00D)

Wireless, high-resolution, time-temperature measurement of foods. Foods, especially ready-to-eat foods available for consumers via retail outlets, may undergo temperature fluctuations due to faulty refrigeration. These fluctuations may induce growth of pathogens and spoilage microorganisms. Continuous temperature monitoring is required to avoid any food safety or quality concerns. ARS-funded scientists at the Center for Food Safety Engineering at Purdue University in West Lafayette, IN, developed a system that can be integrated in delicatessen cases and is capable of acquiring temperature measurements using low-cost tags that can be attached to food packages. The system provides high-resolution temperature measurement that can be integrated into the "Internet of Things" (IoT) through Bluetooth communication capabilities. Integrating the system in retail deli cases can enable real-time risk assessment of stored products with direct notification of the management when irregular storage conditions occur. Implementation of such a system will enhance the safety and quality of ready-to-eat foods. (NP108, C1, PS3, Project No. 8072-42000-077-00D)

Flowing steam decontamination of broiler transport cages. Live-haul cages are used to transport broilers from the farm to a processing facility. These cages are large and expensive; therefore, companies have a limited supply and continually reuse the same cages. *Campylobacter*, a significant human foodborne pathogen, can be readily detected in the feces of broilers from a Campylobacter-

positive flock. Feces left in a cage by broilers that carried *Campylobacter* can contaminate the next broilers placed in the same cage. Studies have previously shown that water spray and sanitizing broiler transport cages is logistically complicated, physically difficult, water intense, and largely ineffective to eliminate *Campylobacter*. ARS researchers in Athens, GA, tested steam as a means to decontaminate transport cage flooring, which resulted in an approximately 99-percent reduction in the number of *Campylobacter* bacteria detected. When the steam treatment was preceded by a 15-second water spray, the *Campylobacter* reduction was improved to 99.99 percent compared with untreated cages. Although *Campylobacter* was not completely eliminated, steam shows potential as an effective method for sanitizing broiler transport cages and to control transfer to previously negative broilers. Lowering the number of *Campylobacter* bacteria on live broilers entering the processing plant would be expected to lessen contamination of fully processed poultry meat products and reduce consumer exposure to *Campylobacter*. (NP108, C1, PS5, Project No. 6040-32000-009-00D)

Eliminating *Campylobacter* in chicken livers. Campylobacter species are significant human foodborne bacterial pathogens specifically associated worldwide with poultry and poultry products. Foodborne outbreaks of campylobacteriosis, the disease ascribed to the pathogen, can often be traced to pâté or mousse prepared from undercooked chicken liver. *Campylobacter* is readily detected on fresh raw chicken livers in the processing plant and at retail. Infections have become so prevalent in the last several years that the USDA, Food Safety and Inspection Service was prompted to call for interventions to decontaminate chicken liver. ARS researchers in Athens, GA, tested heat and cold treatments to lessen *Campylobacter* contamination of fresh chicken livers. Immersion in 60°C water for 5 minutes resulted in significantly lowering *Campylobacter* numbers. Forty-eight hours at −25°C in a household

freezer was moderately effective. When heat and freezing were combined in series, a nearly 99-percent decrease in the number of naturally occurring *Campylobacter* on both the surface and within inner tissue of chicken liver was achieved. Thus, a mild heat process followed by freezing can be recommended for presentation of poultry livers at retail or home and will reduce consumer exposure to *Campylobacter*. (NP108, C1, PS5, Project No. 6040-32000-009-00D)

Simple and portable test for amatoxins. Amatoxins are lethal toxins found in certain mushrooms, particularly the death cap mushroom, which cannot be eaten. Because many inedible mushrooms are physiologically similar to edible mushrooms, many people (and animals) are sickened (and many die) from mistaken consumption. Additionally, most medical and veterinary personnel have difficulty determining which poison a human or animal might have ingested. ARS researchers in Albany, CA, developed an antibody-based immunoassay that can detect as little as 10 ng/ml of amatoxins in both mushroom and urine samples without the need for specialized equipment. The detection of amatoxins in urine samples correlated very well with the traditional methods of using liquid chromatography-mass spectrometry. The speed of analysis and lack of needing trained personnel and expensive instrumentation will offer a quick way to directly diagnose amatoxin-specific mushroom poisonings. The new immunoassay is currently being used and tested by several animal clinics through material transfer agreements and informal collaborations. A patent is pending for the new immunoassay. (NP108, C1, PS3, Project No. 2030-42000-049-00D)

Impact of agricultural runoff on Shiga toxin-producing *Escherichia coli*. Shiga toxin-producing *Escherichia coli* (STEC) are a group of foodborne bacterial pathogens that can be transmitted to humans

mainly through food and water. STEC strains are implicated in more than 270,000 cases of human illness annually in the United States. STECs naturally reside in cattle, and are found in natural creek sediments that are affected by runoff and fecal pollution from agricultural and livestock practices. ARS researchers in Albany, CA, detected STECs from the water-sediment interface of two creeks in the Salinas River Valley of California, an area that is known to be associated with STEC-derived foodborne illness. Shiga toxin-encoding genes were not directly detected in the metagenomes of samples that were culture-positive for STEC, indicating that STEC was present at very low levels in those sediments. Furthermore, there were no significant differences in the abundance of human or cow-specific microbiome sequences between the control and sampling sites, implying a natural dilution of the human inputs. This study provides metagenomic parameters for the Food and Drug Administration to use in enforcing the Produce Rule within the Food Safety Modernization Act. (NP108, C1, P12, Project No. 2030-42000-050-00D)

Vaccination of cattle and impact on intestinal microbiota. Vaccines targeting the bacterial pathogen *Escherichia coli* O157:H7 (O157) in cattle have the potential to reduce O157 colonization and thus reduce carcass contamination. However, non-O157 *E. coli* are part of the normal microbiota, and vaccination against O157 *E. coli* may impact numbers and types of normal bacteria (microbiota) found in cattle intestines. Because the intestinal bacteria play a critical role in animal health, alterations induced by vaccination could affect an animal's immune response and overall health. ARS researchers in Ames, IA, evaluated the impact of O157 vaccination and O157 colonization on the diversity of intestinal microbiota to gauge potential unforeseen consequences of O157 vaccination. Microbiota analysis of fecal samples (which contains intestinal bacteria) from vaccinated and nonvaccinated cattle

indicated a significant correlation between vaccination and alterations in intestinal bacterial populations. Whereas vaccination may be a strategy to limit O157 in cattle, unforeseen consequences of changes in beneficial bacterial populations warrant further consideration. (NP108, C1, PS1, PS2, PS3, and PS5, Project No. 5030-32000-112-00D)

Simple, low-cost CCD camera system for active abrin detection. Abrin is a natural but lethal toxin produced and found in the seeds of the rosary pea (*Abrius precatorius* L.) The toxin has a similar mode of action to that of the select agent ricin, which is found in the seeds of the castor bean plant. There are many ways to test for the presence of abrin, but few assays can distinguish between the active (lethal) and inactive (nonlethal) form of the toxin. ARS researchers in Albany, CA, developed and built a simple, low-cost charge-coupled device (CCD) camera and applied it to cell-based assays. In the presence of active abrin, the cells either produced a color change or a change in their fluorescent glow. The new fluorimetric method was able to detect as little as 0.1 pg/mL of active abrin. This simple and inexpensive method directly adds to the arsenal of tools for the accurate detection of abrin poisoning, which may occur, for example, in cases of intentional food adulteration/contamination. (NP108, C1, PS3, Project No. 2030-42000-049-00D)

Bioinformatic tool for bacterial genome analysis. The development and implementation of next-generation sequencing has significantly improved our understanding of the bacterial genome architecture. However, there are still multiple bioinformatic hurdles to maneuver before a bacterial species becomes an informative annotated genome. Currently, bacterial bioinformatics generally entails using several stand-alone tools that make the process cumbersome and prone to specialist/human error.

Developing technologies to eliminate these errors is a critical research need. ARS researchers in Athens, GA, and Colorado State University developed Reads2Resistome, a bioinformatic tool that streamlines this arduous effort. Reads2Resistome allows users with experience using basic Linux commands to analyze bacterial genomes using either short-read or long-read sequencing technologies. Reads2Resistome takes sequence reads as input and performs assembly, annotation, and genome characterization with the goal of producing an accurate and comprehensive description of the bacterial genome. Included in the analysis is determination and collection of all the antibiotic resistance and virulence genes, and other resistance elements within the main chromosome, or other elements such as plasmids or bacteriophage. The pipeline is executable on both Mac and Linux operating systems and is well suited for institutions and organizations that maintain or have access to a high-performance cluster for analyzing big data. Reads2Resistome is the first pipeline to our knowledge that performs both genome assembly and in-depth genome characterization. The new technology has been made publicly available on GitHub and is accessible to USDA researchers via SCINet. (NP108, C1, PS3 and PS7, Project No. 6040-32000-009-00D)

Predicting *Salmonella* prevalence. *Salmonella* contamination of poultry and poultry products remains a critical concern for the USDA, Food Safety and Inspection Service. Farmers and inspectors alike need a way to predict the prevalence of *Salmonella* during the pastured poultry farm-to-fork continuum so that the correct and appropriate interventions can be applied. ARS researchers in Athens, GA, used random forest modeling, farm-management data obtained through questionnaires, and meteorological data to develop and validate algorithms that were effective at predicting *Salmonella* prevalence. The predictive modeling showed that years farming, broiler flock age, and dominant feed components were

major farm management drivers of *Salmonella* prevalence in preharvest samples, whereas dominant feed components was the most relevant driver of *Salmonella* prevalence in postharvest samples. Average temperature, humidity, and high-wind gust speeds prior to sampling were the meteorological variables that most closely correlated to *Salmonella* prevalence in preharvest samples. These data provide stakeholders with target variables to monitor to determine potential *Salmonella* food safety risks within their management systems. (NP108, C1, PS3, PS5, PS6 and PS7, Project No. 6040-32000-011-00D)

Smartphone-based spectrometer. Industry and regulatory inspectors are required to monitor products for safety as they proceed through the food production and processing continuum. Normally samples are taken and sent to an internal or external laboratory for analysis using various types of assays. A major limitation of many food safety assays is that they require expensive equipment found only in centralized laboratories. Both industry and inspectors would prefer, where possible, that samples obtained in the field be analyzed on site, and data immediately be made available. ARS-funded scientists at the Center for Food Safety Engineering at Purdue University have developed a smartphone-based spectrometer that can resolve the visible range of spectrum in transmission mode and can be used to analyze many types of food safety assays. The overall cost of the spectrometer is only $200 and functions with an app that can visualize, record, and analyze the visible spectrum. The outcome is that this device could be incorporated into many types of assays with visual readouts to allow data to be used at the point the sample is taken, simplifying the assay process, and thus reducing the time required to obtain a result and transfer the data. (NP108, C1, PS3 and PS4, Project No. 8072-42000-077-00D)

COVID antiviral cotton facemasks. During the Coronavirus COVID-19 enforced maximal telework period, ARS researchers at New Orleans, LA, in collaboration with a medical trauma wound dressing company, revealed that a jointly developed cotton nonwoven product exhibited antiviral activity. The natural compound in cotton (hydrogen peroxide) was discovered by ARS and tested by a contract company and was found to have antiviral activity based on a molecular model of SARS-CoV-2 virus. The product exhibited 99.999 percent antiviral activity after 1 hour of contact with the fabric. Nonwoven cotton will be studied with collaborators to determine its ability to inhibit COVID-19, which is caused by the current SARS-CoV-2 virus. Following testing by a secondary company to obtain a Food and Drug Administration-approved ISO test for antiviral textiles, the company plans to develop a prototype for use in facemasks. (NP306, C2, PS2a, Project No. 6054-41430-007-00D)

Removing plastic contamination and increasing cotton's value. Plastic contamination is the single biggest threat to the U.S. cotton industry to date. According to the USDA, Agricultural Marketing Service, most of the plastic contamination in test samples from ginned cotton in the United States originates from plastic material used to wrap the harvested cotton modules formed by state-of-the-art cotton harvesters. Plastic contamination is the major reason for the loss of the premium grade status. U.S.-grown cotton was once well received on the international market for its reputation as the world's reliable source of contaminant-free natural fiber. On an annual basis, the loss is more than $750 million. ARS researchers in Lubbock, TX (with assistance from ARS researchers in Las Cruces, NM), developed a low-cost system that identifies and removes plastic and other contaminants in harvested cotton before being ginned. This system, commercially known as VIPR (for Visual Inspection and Plastic Removal), uses imaging sensors from the cell phone industry with low-cost embedded microcontrollers to identify

contaminants. When a contaminant is detected, a pneumatic system blows the contaminant out of the cotton and onto the floor. Commercial testing shows that the system can operate with detection/removal efficiency of more than 90 percent. This technology was developed, tested, and successfully transferred to a commercial partner and is now being sold domestically and internationally. This system will return "premium grade" status to U.S. cotton and over the next decade is expected to earn the industry more than $7 billion. (NP306, C2, PS2a, Project Nos. 3096-21410-008-00D and 3050-41000-009-00D)

Discovery of a standard reference for wheat "falling number" quality determination. Falling number is an 80-year-old method used the world over to measure the quality of harvested wheat. There has long been a need to identify a stable reference material to standardize the precision and accuracy of machines that calculate falling numbers. ARS engineers in Beltsville, MD, determined that corn starch is an excellent material to serve as a substitute for harvested wheat because of its high precision in falling number tests, long shelf life, and low cost. Government regulatory agencies in Canada, the USDA, Agricultural Marketing Service, and private grain-handling and milling companies are, for the first time, developing the acceptable limits for a worldwide standard chart, based on this standard reference, to reliably determine wheat falling number. (NP306, C1, PS1a, Project No. 8042-44000-001-00D)

Biobased cat litters made from renewable low-value plant fibers. ARS scientists in Peoria, IL, using low-value, invasive Eastern red cedar (ERC) wood chips, developed new absorbents and pest control products. ERC lumber and sawdust were processed for optimal use as a biobased absorbent that contains essential oils shown to be repellant and/or toxic to fleas and ticks. An absorbent formulation consisting of 10 percent ERC biochar, 84 percent ERC wood fibers, 4 percent guar gum, and 2 percent mineral oil

provided excellent suppression of odors, including the major cat urine odor compound, and had physical and chemical properties equal to or superior to the top three biobased cat litters currently on the market. A U.S.-based pet care company has signed a confidential agreement to work with ARS scientists on this cat litter and an invention disclosure has been approved by the ARS Chemical Patent Committee. (NP306, C1, PS1c, Project Nos. 5010-41000-167-00D and 5010-41000-169-00D)

Unlocking the genetic resistance of soft winter wheat preharvest sprouting (PHS). PHS is the germination of wheat grains in the field before harvest following 2 or more consecutive days of rain with cool temperatures. These weather conditions occur in the soft winter wheat growing region about once every 2 years and farmers can lose approximately 30 percent of their crop value, which translates into approximately $420 million annually in the United States. Much is known about the biochemical process of PHS but little is understood about the genetics of PHS. Because its genetic nature is not well understood, few markers exist for breeders to use in developing resistant lines. ARS scientists in Wooster, OH, completed a survey of PHS resistance in a population of nearly 200 diverse soft wheat breeding lines over 3 years and over 2 years in a second, and a more diverse population of older varieties. Nine soft winter wheat varieties were identified as PHS-tolerant over multiple years under PHS-inducing conditions. These findings provide important information for breeders about varieties with tolerance to PHS and the potential for future breeding of PHS resistance. (NP306, C1, PS1a, Project No. 5082-43440-001-00D)

First ever control of blueberry fruit rot. Control of postharvest blueberry fruit rot is important to maintain domestic and international marketing and shelf life, and to reduce fruit loss and waste. To date

no products have been registered specifically to control blueberry fruit rot. ARS researchers in Parlier, CA, tested reduced-risk fungicides as a preharvest treatment and a postharvest continuous ozone fumigation to control blueberry fruit rot. A mixture of the fungicides fludioxonil and cyprodinil was found to significantly reduce gray mold and *Alternaria* rot, the two most important postharvest rot diseases of blueberries grown in California. Continuous ozone fumigation at low doses significantly reduced gray mold and its fruit-to-fruit spread. These treatments provide new tools for control of commercial postharvest fruit rot diseases of blueberries. (NP306, C1, PS1a, Project No. 2034-43000-039-00D)

ARS develops the first automated peanut sampling system. Every load of peanuts a farmer delivers for sale is sampled and graded by the USDA, Agricultural Marketing Service (AMS) to determine its quality and value. Each load is parked beneath an overhead pneumatic sampler where human operators crawl through the truckload of peanuts to insert a probe up to 15 times in specified locations to obtain samples for testing. ARS engineers in Dawson, GA, designed and installed an instrumentation and control system that automatically senses the load of peanuts under the sampler, locates the trailer, and controls the sampler to probe the trailer according to the prescribed probe patterns. AMS personnel conducted tests for 2 years and have approved the control system for installation at commercial peanut facilities for official sampling. This device reduces the reliance on seasonal labor and improves the consistency and accuracy of the sample used for determining peanut quality and value. (NP306, C1, PS1a, Project No. 6044-41430-006-00D)

High-value gluten-free fiber from grapefruit citrus peel waste. When citrus fruits are processed into juice, the waste material is usually converted into low-monetary-value animal feed and molasses in a process that is energy demanding and costly. This process destroys compounds within the residues that, if recovered, can be used to make high-value products such as gluten-free fiber. Low-cost and low-energy-use steam explosion systems have been used in the past to recover valuable compounds from orange juicing waste residues but never from grapefruit juicing residues. As part of a research agreement with an industry partner, ARS scientists in Fort Pierce, FL, conducted steam explosion on grapefruit processing residues and successfully recovered gluten-free fiber, high-value pectin, phytonutrients, and essential oils. These scientists continue to interact with stakeholders interested in using steam explosion on an industrial level for processing grapefruit peel waste residues at their facilities into high-value bioproducts. (NP306, C1&2, PS1a&2b, Project No. 6034-41000-017-00D)

Making pulses a novel, issue-free, food ingredient. Pulses (dried beans) provide valuable health benefits in the diet but are a relatively minor component in the U.S. food economy due to issues such as long cooking time, beany taste, flatulence, and abdominal discomfort. New processing methods are needed to provide pulse-based functional food ingredients in a form that facilitates their incorporation into various food products while minimizing negative characteristics. ARS scientists in Peoria, IL, successfully used jet-cooking to separate navy bean flour into readily obtained water soluble and insoluble fractions while leaving behind almost all the flatulent sugars and the “beany” taste. The researchers discovered the insoluble fractions could serve as a fiber and protein ingredient to fortify bread or spreadable food products, while the soluble fraction has good emulsification and foam properties, making it a potential substitute for egg whites. Because the isolated fractions can be dried

and reconstituted or used directly, food producers and consumers can readily adapt them into their manufacturing or food preparation processes. (NP306, C1, PS1b, Project No. 5010-41000-168-00D)

Potato postharvest quality evaluations and release of new potato cultivars. Acceptable processing quality after storage is an essential attribute of a successful potato variety. The standardized evaluation procedures developed and used by ARS scientists in East Grand Forks, MN, a worksite of the ARS research unit in Fargo, ND, have been an important component of the overall process for evaluation and release of new cultivars by Federal and State cooperators nationwide. In the past year, in support of Federal and non-Federal public breeding/screening programs, 139 advanced breeding lines were analyzed for storage/processing quality at multiple storage temperatures and durations. Since 2015, 17 chip clones and 14 fry processing clones identified in East Grand Forks to have superior storage quality have advanced through rigorous national variety testing platforms aimed at providing potato industry stakeholders a high-quality processed potato product throughout storage. Data from these analyses have contributed to the national release of new potato varieties with superior processing quality throughout storage. (NP306, C1, PS1a, Project No. 3060-21430-007-00D)

ARS annual Hard Winter Wheat Crop Quality Survey. ARS scientists in Manhattan, KS, completed the annual Hard Winter Wheat Crop Quality Survey involving the evaluation of more than 600 individual and more than 100 composite, hard winter wheat samples for milling and baking quality. The resulting data were posted in real time to a web page managed by Plains Grain, Inc., as the harvest progressed; the data were also used by U.S. Wheat Associates in its final annual report for domestic and international export customers. (NP306, C1, PS1a, Project No. 3020-44000-026-00D)

Corn starch: It's an emulsifier and a pesticide. An emulsifier allows two normally insoluble materials to become a stable mixture. Many industrial emulsifiers use carcinogenic or highly hazardous ingredients. As a result, there is a constant need for improved industrial emulsifiers that provide biobased and safe alternatives. ARS scientists in Peoria, IL, have developed an economical emulsifier that uses corn starch and a vegetable oil. This new emulsifier (called an AIC) forms suspensions of oil in water, which are stable for months and makes water slicker, allowing the AIC-water solutions to lubricate parts and allowing for efficient cleaning. In addition, the AIC can control Gram-positive bacteria, yeast, mold, fungi, and some insects, including termites. The ability of corn starch to function as both an emulsifier and pesticide is highly attractive and has given it a higher value. This new technology allows for the replacement of imported emulsifiers or those that use hazardous ingredients or processes. These new products are being promoted by industry resulting in new applications for corn starch and benefiting corn producers, processors, and consumers. (NP306, C1 & C2, PS1c, & PS2b, Project No. 5010-41000-166-00D)

Treatment of poison ivy dermatitis. ARS researchers in Oxford, MS, in collaboration with ElSohly Laboratories, Inc. and university researchers, are developing preventive treatments for poison ivy dermatitis. Development to date has shown that derivatives of urushiol, the oil in poison ivy that causes dermatitis, to be effective in animal models for desensitization to poison ivy dermatitis and to have desirable bioavailability and toxicological properties. This product has been given "investigational new drug" (IND) status by the Food and Drug Administration. (NP306, C2, PS2a, Project No. 6060-41000-012-00D)

Economically fermenting xylose into ethanol. Xylose is cheap, abundant sugar naturally present in biobased materials, and for the past 30 years, scientists have been working to develop brewer's yeast that ferments this sugar into ethanol. Although the process has been successful, the rate of fermentation is still low by industrial standards. To speed up the fermentation process, xylose needs to gain faster access into the yeast cells, which occurs via transporter proteins. ARS researchers in Peoria, IL, have developed a yeast that has two novel xylose transporter proteins, thus improving the rate of fermentation rate by 10 percent. Improving the rate of fermentation allows an ethanol plant that produces 40 million gallons per year to produce 4 million extra gallons, bringing down the cost of ethanol production. Increasing fuel ethanol production directly benefits farmers by creating demand for their unused agricultural residues through more efficient biorefining. (NP306, C3, PS3a, Project No. 5010-41000-178-00D)

A novel "green" process for germinated, brown rice beverage. The functional beverage market offers a consumer-friendly mechanism to rapidly develop healthy alternates to dairy products. ARS researchers in New Orleans, LA, developed methods to deliver superior all-natural value-added rice beverages using green technologies. Green technologies for food processing were defined as being sustainable and less harmful to the environment, and entails the use of safe, natural chemical processes to transform raw products into value-added foods and ingredients. The researchers described a novel method for germinating and processing unstabilized raw brown rice that leads to a completely green process and free-flowing soluble matrix that renders a beverage. The "green" sprouted brown rice beverage has no additives, fortifications, added oils, or salts. The method has very low inputs, requires minimal equipment, and is applicable for both germinated brown and colored rice varieties. An

invention disclosure was submitted, resulting in the transfer of this knowledge through publication. The global market for plant-based alternatives to dairy beverages is expected to surpass $34 billion by 2024. This new plant-based, protein-rich functional beverage with proven health-beneficial attributes will have a positive economic impact on that market. (NP306, C1, PS1a, Project No. 6054-41000-107-00D)

Stopping the degradation of sugarcane during temporary storage. Microbial deterioration of sugarcane starts as soon as it is harvested. Harvested cane is commonly stored while awaiting processing, but significant sugar losses occur during storage because of microbial degradation. ARS researchers in New Orleans, LA, working with a private company tested liquid sodium permanganate application to the sugarcane during storage and compared its ability to prevent sugar loss via microbial degradation against other currently used products (bleach, biocide). Sodium permanganate was better than bleach at preventing sugar loss to microbial degradation. A preliminary economic analysis estimates an annual revenue increase for the average Louisiana sugarcane factory to be approximately $1.95 million using sodium permanganate. Expanded to the entire Louisiana sugar industry, this early treatment system could increase the annual revenue of the industry by a net of 1.64 percent or $44.4 million. (NP306, C1, PS1b, Project No. 6054-41000-111-00D)

A new starter culture accelerates the conversion of sugars to acids in the fermentation of commercial pickle production. Out of 243 bacterial isolates from commercial cucumber fermentations, ARS scientists in Raleigh, NC, identified 18 cultures that were able to ferment cucumbers under various conditions of temperature, pH, and salt content. Cultures that were unable to produce potentially carcinogenic biogenic amines in cucumber fermentation brines were selected for further study. These

starter cultures produced exopolysaccharides (sugar chains that serve as prebiotics) that feed helpful bacteria that are naturally present in the human gut. Five of the 18 cultures were found to be suitable for use as starter cultures in low-salt fermentations currently undergoing commercial development. One starter culture was transferred to the private sector for commercial production and was used in the United States and in Germany, Mexico, and Turkey for the manufacture of cucumber pickles. The availability of these starter cultures enables the continued and expanded use of the technology to manufacture pickles with low salt and minimized environmental impact. (NP306, C1, PS1b, Project No. 6070-41000-008-00D)

Stevia has no negative effect on the gut. Stevia is a popular plant-based, low-calorie sweetener loved by consumers who consume a low-carbohydrate diet. Stevia is a natural plant-based sweetener extracted from the leaves of the *Stevia rebaudiana* plant using water or ethanol and then dried. Recently, questions have been raised about the safety of stevia and similar extracts. ARS scientist in Wyndmoor, PA, studied the effect of stevia on models of human gut bacteria and found that stevia has no adverse impact on the bacteria in the human gut models. (NP306, C1, PS1b, Project No. 8072-41000-102-00D)

Stopping the yellowing of wool. Wool is a major textile fiber obtained from agricultural animals. However, the long-term exposure of wool to sunlight often causes yellowing and reduces its commercial value. ARS scientists in Wyndmoor, PA, have developed a simple treatment that decreases yellowing by treating wool using a vitamin-like substance, para-aminobenzoic acid (PABA), in combination with high-absorbance ultraviolet (UV) light. The yellowing rate as measured using an absorption-metric colorimeter was greatly diminished when wool fabrics were treated with PABA and UV light. An

invention disclosure patent has been submitted and ARS scientists are seeking an industrial partner to commercialize this new process to preserve wool. (NP306, C2, PS2a, Project No. 8072-41440-024-00D)

Improved packaging film made from renewable, inexpensive cotton waste materials. There is increasing concern about the environmental impact of nondegradable plastics accumulating in landfills and the oceans. One solution is to replace some of these fossil-fuel-based nondegradable plastics with water-soluble, biodegradable plastics. Poly(vinyl alcohol) (PVOH), derived from plant sources, is water-soluble and biodegradable and the perfect candidate for this replacement. ARS scientists in Peoria, IL, discovered that when PVOH is blended with cotton gin trash (CGT, a waste material left over after cotton processing), it resulted in a low-cost biodegradable composite that is applicable for making composite films or plastics. When CGT is chemically modified, properties of the blended films were further improved for diverse applications. Using CGT in a higher value product, like biodegradable plastics, increases the value of U.S. cotton coproducts, which benefits U.S. cotton farmers and helps mitigate plastic pollution. (NP306, C2, PS2a, Project No. 5010-41000-174-00D)

Green technique for producing cellulosic composites with improved structural properties. Wood is mainly composed of cellulose and lignin. To remove the lignin is a complex and expensive process that destroys the inherent structure of the wood. ARS scientists in Peoria, IL, have developed a unique green method for removing lignin from woody biomass that leaves the woody cellulosic structure intact. The removal of lignin from woody biomass is accomplished by using acetic acid and hydrogen peroxide. Novel composites can then be produced by infusing the lignin-free cellulosic with biobased polymers (such as corn starch or corn-derived polylactic acid), which have improved properties. A variety of

cellulosic-based materials have been treated in this fashion, including pine and oak. Non-woody samples, such as soy hulls or alfalfa, can also be processed to provide cellulose composites. The wood composites produced using materials from corn will benefit corn growers and producers as well as tree processors by providing another product line for corn and woody products. (NP306, C2, PS2a, Project No. 5010-41000-174-00D)

New renewable, plant-based engine oil additive. There is a great demand in the United States and the world to find new biobased engine additives to help improve lubricant issues found in fossil fuel-based oils. The purpose of an oil is to provide lubrication between two moving metal surfaces. The oil must be of low viscosity (water-like) to penetrate the contact areas yet be viscous enough to provide separation between the moving surfaces at all operating temperatures. As oil heats up in an engine, its viscosity changes and good separation of the moving parts is no longer maintained. ARS scientists in Peoria, IL, used ARS-created and commercialized estolides (made from sunflower and soybean oils) to develop a new type of engine oil additive that solves these engine lubrication problems. When small amounts of these materials are added to an engine oil, the oil's viscosity remains nearly constant over a broad range of temperatures. These new materials are beneficial to farmers, consumers, and retailers because they are environmentally friendly, improve utilization of soybean and sunflower production, and enhance economic security for rural communities. (NP306, C3, PS3b, Project No. 5010-41000-171-00D)

Novel high-value sorghum coproducts. An economic obstacle to producing cellulosic biofuels is the low market price of bioethanol relative to its operating and very high capital costs. ARS researchers in Peoria, IL, working with University of Illinois scientists in Urbana, solved this problem by developing a

new process that allows glucose and xylose to be extracted separately from sorghum grain. Glucose is conveniently fermented to ethanol. The xylose syrup was concentrated and then converted to a nutritional product using an engineered brewer's yeast from the ARS microbial collection. The product was beta-carotene, which our bodies use to produce vitamin A. This research will be of interest to those who work on commercializing cellulosic biofuels and more generally to agriculturally-based refiners and farmers looking to find new markets for their crops. (NP306, C3, PS3a, Project No. 5010-41000-176-00D)

New biorefinery-compatible oily yeast strain platform for synthetic biology. Over 1 billion tons of cellulosic biomass (the structural portion of plants), which can be converted into biofuels and biobased products, can be available throughout the United States without impinging on corn and other row crop production. ARS researchers in Peoria, IL, identified a yeast named *Candida phangngensis* that is suitable for commercial development, closely related to existing commercial yeast strains used in synthetic biology, and generally regarded as safe. The new yeast strain produces a plant-like oil from cellulosic sugars and can be transformed to grow on all biomass sugars to produce even more oil. This new strain is expected to advance the economic feasibility of high-quality biodiesel and jet fuels from renewable herbaceous and woody biomass, reducing U.S. dependence on fossil fuels while supporting rural economies and conserving the environment. (NP306, C3, PS3a, Project No. 5010-41000-177-00D)

Identification of genes for degrading plant biomass. Renewable conversion of plants to products begins with breaking down the fibers in plant material. In nature, fungi do the heavy lifting in biomass breakdown. ARS scientists in Peoria, IL, collaborated with the Joint Genome Institute and scientists

from Colombia and the Netherlands to decode the genome of a unique fungus for that natural process. This is the first in-depth genome/transcriptome analysis in an understudied group of fungi with powerful machinery for breaking down plant fibers. More than 50 new genes related to biomass breakdown were identified. This fungus has an arsenal of genes and enzymes needed to break down biomass fibers. The genes and enzymes can be "borrowed" to break down plant polymers and make value-added fuels and chemicals. This research and these results will benefit producers of renewable products who seek effective enzymes to deconstruct the fibers in plant biomass. (NP306, C3, PS3a, Project No. 5010-41000-178-00D)

Use of nano-proteins to provide an antifogging surface. Antifogging agents are chemicals that prevent the condensation of water in the form of small droplets on a surface. Without antifogging treatment, condensed water forms fog-like droplets on the surface of glass or plastics and scatters light, causing low visibility. ARS scientists in Peoria, IL, have improved on a previously patented ARS invention to produce protein nanoparticles that outperform commercial antifog solutions. These biodegradable nanoparticles are made using proteins (from wheat, soybean, or milk) combined with a petroleum-based material. Any surface that may have water fogging or beading on it will benefit. This includes surfaces such as windows on cars, boats, homes, and buildings. In addition, eyewear, such as eyeglasses, and medical and swim googles, will also benefit. End consumers will benefit, and depending on the protein used, so will farmers and stakeholders in the wheat, soybean, and milk value chains. (NP306, C3, PS3a, Project No. 5010-44000-053-00D)

Improved products using nanocellulose derived from corn stover. Cellulose is the substance that is responsible for a plant's strength. If cellulose is reduced to a nano scale (one billionth of a meter), it is called nanocellulose (NC). NC produced from corn stover was developed by ARS scientists in Peoria, IL. NC has been shown to provide value in many end-uses and products, including polymer blends, medical devices, cosmetics, and waste treatment. In all of these applications, the NC must be pumped from one location to the next. For the full value of corn stover NC to be realized, its flow properties must be understood. The scientists used state-of-the-art techniques to determine the flow properties of NC suspensions, which will allow for the production of improved NC-based products. Corn producers and processors will benefit from developing a high-value use from what is normally left over on the corn field. (NP306, C3, PS 3a, Project No. 5010-44000-053-00D)

New analytical techniques to characterize silver nanoparticle-treated textiles. Silver nanoparticles are added to clothing for their powerful ability to kill bacteria and fungi and the odors they cause. To develop safe and reliable nanoparticle-enhanced products, it is essential to have proper analytical techniques that evaluate the resulting technologies and products. However, currently available techniques are complicated, destructive, expensive, and time consuming. ARS researchers in New Orleans, LA, developed two simple, cost-effective, fast, and accurate surface-enhanced Raman spectroscopic methods to quantify silver nanoparticles. The first method, which uses plasmonic hot spots of aggregated nanoparticles, measures silver nanoparticles in a (washing) solution. The second method, which uses a dye to generate a distinctive Raman signal, measures silver nanoparticles in a solid (textile) material. These methods are extremely sensitive, accurate, and better than conventional methods in distinguishing silver nanoparticles from other silver species and mapping the distribution of

nanoparticles in textiles. ARS researchers verified the uniformity of the developed silver nanoparticle-embedded cottons and their washing durability. The first method was supported by the ARS Innovation Fund and the National Science Foundation, and its novelty was highlighted as a featured article on the front cover of the journal Analytical Methods. (NP306, C2, PS2a, Project No. 6054-41000-106-00D)

ANIMAL PRODUCTION AND PROTECTION

National Programs:

- **Food Animal Production, NP 101**
- **Animal Health, NP 103**
- **Veterinary, Medical, and Urban Entomology, NP 104**
- **Aquaculture, NP 106**

A high-quality cattle gene atlas. The goal of genomic analyses in livestock is to make sense of the genome to understand and improve important livestock traits. With modern technologies, it is possible to localize variation in traits to regions of the genome, but it can be difficult to determine the gene, and the change in the gene, responsible for the trait. For some genes where the functions are not well characterized, it can also be difficult to determine what parts of the body are involved in controlling the trait. ARS scientists in Beltsville, MD, developed a comprehensive tissue-gene atlas for cattle by integrating their own information with publicly available information on gene regions associated with traits, genes expressed by tissues, and changes in gene chromosome structure that are known to control gene function. This high-quality cattle gene atlas links these three data sources for the first time and

provides an important tool for discovering the tissues, genes, and genome structure that control traits in cattle. (NP101, C2, PS2A, Project No. 8042-31000-001-00D)

Chromatin modification in placenta of swine varies with season. Chromatin modifications are known to alter gene expression, and therefore contribute to changes in traits like fertility. In pigs, pregnancy rates are lower when breeding take place during the summer, but the reasons are not known. The swine industry controls temperature and photoperiod by using climate-controlled housing, but seasonal reductions in farrowing rates and litter size still occur. Producers offset these losses by increasing their summer breeding stock 20–25 percent and subsequently increasing the number of breedings by 15 percent, all at significant cost to the industry. ARS scientists in Clay Center, NE, and University of Wisconsin collaborators found that placentas developed from summer breeding had greater expression of genes associated with chromatin modification than placentas from winter breeding. These data suggest seasonal differences in the expression of chromatin modification genes may contribute to seasonal infertility by altering the expression of key genes. Treatments that reduce unfavorable placental chromatin modification pathways during the summer could reduce seasonal reproductive inefficiency losses estimated at more than $600 million annually. (NP101, C1, PS1A, Project No. 3040-31000-095-00D)

Development of 3-dimensional (3D) imaging to predict the weight of pigs. Continuously monitoring animal weight would benefit producers by ensuring all animals are gaining weight as expected and would assist in precision feeding of pigs. ARS scientists in Clay Center, NE, conducted research on commercially available 3D imaging to predict live animal weight in grow-finish pigs. They collected

920 3D images and weights from a population of grow-to-finishing pigs equally divided by sex across three commercial lines. The 3D images were used to calculate the volume of each pig, and scientists developed an equation to predict pig weight from the calculated volumes regardless of sire line or sex. Methods for monitoring the growth and physical condition of animals without animal handling will reduce labor, improve animal well-being, and increase the profitability and sustainability of production. (NP101, C1, PS1C, Project No. 3040-31000-097-00D)

Development of a verified algorithm to correctly assign sequencing level genotypes to crossbred cattle using low-cost, low-coverage genotypes. Detecting all the DNA variation in each individual animal can be done by genome sequencing, but is too expensive for routine genomic analyses of traits. The full DNA variation of individuals is necessary to effectively predict trait differences caused by DNA variation. Methods to correctly assign complete sequence-level DNA variation of key ancestors to offspring using low-cost genotyping would improve genomic predictions and save industry the expense of sequencing every animal. ARS researchers in Clay Center, NE, assembled genomic sequences from individuals with many descendants in a crossbred population representing the 18 most predominant beef breeds in the United States, and combined it with publicly available sequences representing beef and dairy breeds. In collaboration with Gencove, Inc., these sequences were analyzed to determine DNA variants that typically occurred together. Those relationships were then used to predict all the variants in the genome from a low-cost, low-coverage genome sequencing to generate a low number of initial genotypes. The low-cost sequencing approach for generating initial genotypes results in better accuracy of DNA variation assignment than genotypes obtained using SNP chips, the most common approach to genetic marker detection. This new method will enable more effective trait-genome associations at a

lower cost than currently available SNP chips. Producers will include a larger portion of animals, at low cost, for genetic evaluation programs, and predict genotypes up to the genome sequence level. This will improve selection accuracy and increase genetic gain, and lead to a faster rate of improvement in valuable beef traits for the industry. (NP101, C2, PS2A, Project No. 3040-31000-100-00D)

Classification of beef carcasses for top sirloin tenderness. Recently developed certification standards for tenderness have given the beef industry added impetus to implement a tenderness-based marketing system. For retailers to effectively execute a tenderness-based marketing strategy, retailers must be able to market all meat derived from the loin and rib from a qualifying carcass as certified tender. Currently, the certification does not include top sirloins, which are derived from the loin and represent a substantial retail meat cut feature. ARS scientists in Clay Center, NE, determined that tenderness classes based on the VBG2000 beef grading camera allowed for identification of carcasses with more favorable top sirloin tenderness. This work showed that tenderness testing with a beef grading camera in combination with refrigerated aging for 28 days can produce consistently tender top sirloin steaks that qualify for a guaranteed tender marketing claim. This could lead to more than $18,000,000 in added annual revenue for the U.S. beef industry. (NP101, C3, PS3A, Project No. 3040-31430-006-00D)

Using nitrous oxide (laughing gas) to euthanize piglets is as effective as using carbon dioxide and may be more humane. A significant component of livestock care is determining when to euthanize hurt or sick animals that will not be able to recover and how this should be conducted to prevent further suffering or injury. Previous research that assessed physiological stress reactions in piglets indicated euthanasia using nitrous oxide instead of carbon dioxide could be less stressful. ARS scientists in West

Lafayette, IN, followed up on these findings with additional research on the potential of using nitrous oxide to euthanize piglets that are seriously ill, injured, or unable to thrive because of congenital issues or other factors. Based on several observations, including EEG readings that assessed brain wave activity, they concluded that nitrous oxide may be a suitable alternative to carbon dioxide and a more humane alternative for pigs that must be euthanized. (NP101, C1, PS1C, Project No. 5020-32000-013-00D)

Grazing red clover reverses fescue toxicosis in cattle. Fescue toxicosis, characterized by reduced blood circulation, affects cattle, sheep, and goats in large sections of the Mid-Atlantic region of the United States. It is caused by toxins produced by a fungus infesting fescue grass common in regional pastures. The pasture legume red clover contains isoflavones that can improve blood flow in animals affected by fescue toxicosis. Interseeding red clover into toxic tall fescue pastures is suggested to mitigate fescue toxicosis, but the direct impact of interseeding red clover on blood flow and performance has not been assessed. ARS scientists in Lexington, KY, evaluated the impact of interseeding red clover on cattle grazing toxic tall fescue. Cattle grazing pastures with interseeded red clover had greater growth performance and exhibited increased blood flow post-grazing. This research showed interseeding red clover in toxic tall fescue pastures can reverse some of the negative effects associated with fescue toxicosis. Notably, this is the first study that demonstrated cattle grazing interseeded red clover is an effective pasture management strategy to elicit the benefits of isoflavones on blood flow. (NP101, C1, PS1A and PS1C, Project No. 5042-32630-003-00D)

Stored livestock germplasm is a valuable resource for livestock producers. The livestock industry relies on the National Animal Germplasm Program (NAGP) collection to provide historical samples of genetic diversity and increasingly uses the collection to address threats such as disease and shrinking genetic diversity. To support this critical food security need in the future, ARS scientists in Fort Collins, CO, continue to add to the animal germplasm collection, which in FY 2020 reached the threshold of more than 1 million samples, and greatly expanded its diversity. Demonstrating its use, Brangus breeders found a mutation that causes white eye disease. The NAGP collection contained the only sampling of an important key ancestor (born in 1982) that tested negative for the condition. Genomic testing can be used to eliminate such mutations, but comprehensive testing is cost-prohibitive. Testing key sires can indicate that their offspring do not need testing if the sire and dam are negative for the disease. The NAGP sample of a key sire reduced the number of cattle tested by 150,000 animals and saved the industry about $1.5 million. In a second example, the Nation's largest seller of beef bulls reintroduced 1980s–1990s genetics to restore genetic diversity to their breeding program. This breeder accessed the NAGP collection for bulls born in 1987 and 1993 with the desired genetics and produced approximately 70 embryos that were implanted in cows that will soon calve. These recent examples highlight the industry value of the NAGP with its diverse genetic collection to address current threats. (NP101, C2, PS2C, Project No. 3012-31000-006-00D)

New method to improve the identification of genetic markers for feed efficiency. Typical studies to identify genetic markers for livestock traits include several thousand animals and thousands of genetic markers. Genotyping, analysis, and interpretation costs associated with the large resulting data set is a challenge to producers wanting to implement genomic selection. To reduce genomic selection's cost and

complexity, an improved ability to narrow genotyping to the most appropriate markers to test for association with specific traits is needed. Using tissues relevant to digestive processes from high and low feed efficient pigs, ARS scientists in Clay Center, NE, developed a methodology that used gene expression data to rank the likelihood that the genes contribute to feed efficiency. To provide a reduced set of markers for analysis, scientists selected 10 different groups of genes and markers for separate trait association analyses based on different relationships to criteria related to feed efficiency. Scientists found 36 markers were associated with feed efficiency; 29 were linked with genes already known to have associations with feed efficiency, demonstrating prescreening helps select for relevant genes and markers. A less targeted approach using thousands of genes and markers evaluated many markers, most of which had no influence on the trait. Though they did raise the threshold for statistical significance, the analysis resulted in identifying only two markers associated with feed efficiency. Neither of those markers were in genomic regions previously associated with feed efficiency and, despite using stringent criteria, may be spurious. The novel strategy for using gene expression information to preselect markers for genomic analysis is a powerful approach for identifying economically important livestock traits markers. The markers identified in this study are available to commercial genotyping companies for producers to improve pig feed efficiency. (NP101, C2, PS2A, Project No. 3040-31000-097-00D)

Optimal donor age for transplantation of ovarian tissue in the turkey. For most livestock species, frozen sperm effectively captures the entire genome because sperm contains both sex chromosomes (X and Y). However, in birds the sex chromosomes are W and Z and males are ZZ. Sperm from male birds only contains a single sex chromosome, so frozen sperm does not preserve the unique W female sex chromosome. An alternative approach to the preservation of the entire genome in birds is to freeze

immature ovarian tissue for storage, and then thaw and transfer it into recipients. Stem cells in the transplanted ovarian tissue then undergo meiosis to generate eggs derived from the tissue donor. ARS scientists in Beltsville, MD, in collaboration with scientists in Canada, took a step toward developing methods to preserve and transfer ovarian tissues in turkeys. Using fresh ovarian tissue, they determined the optimal age to recover and transplant ovarian tissue is 7 days post-hatch; 91 percent of grafts attach and grow if ovarian tissue from 7-day-old donors is transplanted into 2-day-old recipients. This result represents a major advancement in preservation of turkey germplasm, because turkeys are an agriculturally important species with historically poor sperm cryopreservation success. (NP101, C2, PS20, Project No. 2018 8042-31000-110-00D)

Genome sequencing of the weaning-associated fungus *Kazachstania slooffiae* to understand its potential role in piglet growth and health. Weaning is a period of stress and environmental change for piglets, and they experience a greater incidence of diarrhea and other digestive problems. Recent studies indicate there are dramatic changes in fungal microorganisms after weaning, and this change may contribute to the growth and health of weaned piglets. ARS scientists in Beltsville, MD, isolated *Kazachstania slooffiae*, the most dominant post-weaning fungus in healthy piglets, and sequenced its genome. Genes identified from this sequence suggested that *K. slooffiae* has positive interactions with beneficial bacteria in the piglet gut, signifying a strong beneficial role. Sequencing this genome is a critical first step for investigating the effects of this microbe in piglet growth and health. These results support the concept that *K. slooffiae* can be used as a naturally derived probiotic to enhance piglet growth. (NP101, C1, PS1A and PS1C, Project No. 8042-31440-001-00D)

Development of a safe and effective African swine fever virus vaccine -ASFV-G-delta I177L. African swine fever (ASF) is a devastating and highly lethal disease of pigs for which there are no commercial vaccines. One of the most significant knowledge gaps that has hindered scientists from developing a safe and effective ASF vaccine is the lack of genomics information on the function of the virus's 150 genes. ARS scientists at Orient Point, NY, successfully developed genetic engineering techniques that systematically delete genes from the ASF viral genome to determine their function. Pathogenicity studies in pigs with these altered viruses led to the discovery of essential genes for ASF viral replication, host immune evasion, and determinants of virulence. Gene identification provides potential targets for a rational design of safe and efficacious gene-deleted vaccines. The most recent vaccine candidate is the discovery of a genetically engineered gene-deleted live attenuated vaccine strain called ASFV-G-delta I177L. This vaccine strain was shown to be safe and effective and exceeded the performance of other ASF vaccine candidates. For the first time, the ASFV-G-delta I177L vaccine was shown to fully protect pigs against ASF with a low dose of vaccine virus. The safety characteristics of the vaccine include no adverse events even when high doses of the vaccine were administered to pigs. A patent covering the development ASFV-G-delta I177L was filed and several commercial partners initiated the process of licensing ASFV-G-delta I177L. ARS scientists have established an agreement with one of these companies to initiate the commercial development of the vaccine. (NP103, C1, PS1a, Project No. 8064-32000-060-00D)

Improved computer modeling to predict susceptibility of different species to infection with severe acute respiratory coronavirus 2 (SARS-CoV-2). Viruses need to enter a cell to replicate and cause infection. Viral entry begins with attachment between a virus protein and a cell receptor(s), which

allows the virus to enter the cell. Once inside the cell, the virus initiates replication and starts the race between host immunity and infection. For coronaviruses, the spike protein on the viral surface is responsible for cell receptor binding and cell entry. Several groups report that SARS-CoV-2 uses the angiotensin-converting enzyme 2 (ACE2) as the primary receptor for cell attachment. The susceptibility of both wild and domestic animals to SARS-CoV-2 and the potential for its zoonotic transmission is a public health concern. Assessing the potential for zoonotic transmission includes: (1) screening to identify the animal species that was infected originally and passed SARS-CoV-2 to humans; (2) determining if animal hosts can amplify SARS-CoV-2, which could increase its infectious potential; and (3) determining the current risk of infected people passing the virus to animals, particularly domestic species. The latter could result in an amplifying zoonotic cycle of human to animal to human transmission that could worsen SARS-CoV-2 evolution and prevalence. ARS researchers in Ames, IA, evaluated cross-species ACE2 genetic diversity in expression and functionality to determine susceptible tissue types and susceptibility of different animal species to SARS-CoV-2. The analysis predicted the limited potential of livestock transmission of SARS-CoV-2. Results also revealed that evolutionary changes in the genetic sequence of ACE2 receptors in domestic animals, including dogs, pigs, cattle, and goats, may have resulted in restricting SARS-CoV-2 infections. (NP103, C1, PS1b, Project No. 5030-32000-118-00D)

A reference typing method and related public database for *Mycoplasma bovis*. *Mycoplasma bovis* is a bacterial pathogen that causes significant respiratory disease in cattle and bison. An objective, standardized, and discriminatory method to categorize bacterial isolates is needed to understand how this bacterium spreads and whether particular families of isolates have an enhanced ability to cause disease.

Two different genetic typing methods have recently been developed for *M. bovis*, but the related data available fail to reveal whether one is superior to the other. To resolve this issue, a subcommittee of the International Organization for Mycoplasmology requested ARS researchers in Ames, IA, to organize and lead a multinational effort to compare the two methods and identify a single approach as a universal typing scheme. ARS scientists defined a single, highly informative method employed as the reference typing scheme for *M. bovis* using bioinformatics tools to analyze genome sequences from more than 450 isolates obtained from every major region of the world. The scheme and a related open-access, curated database are freely available online at pubmlst.org/mbovis. The database integrates genetic data with isolate-specific information, such as geographic and anatomic origin, year of origin, clinical presentation of the animal of origin, and other factors. This comprehensive resource currently includes more than 1,200 isolates and has been accessed by more than 100 animal health researchers and clinicians around the world. Information from the database was a critical part of several recent studies that defined local, regional, and global transmission patterns of *M. bovis*. Such insights into the population structure and epidemiology of *M. bovis* will support the development of rational, data-driven management and treatment practices that will positively impact livestock farmers and consumers of related products. (NP103, C4, PS4a, Project No. 5030-32000-116-00D)

Validation of an international standard PPD (purified protein derivative) for skin testing cattle. Bovine tuberculosis, caused by the bacterium *Mycobacterium bovis*, is a global problem impacting international and domestic trade. Harmonization and acceptance of diagnostic tests for bovine tuberculosis are important production and trade issues. ARS scientists in Ames, IA, worked internationally with other bovine tuberculosis research labs and the World Organization for Animal

Health to evaluate and validate a new international standard tuberculin, a sterile protein extract *of M. bovis* that is used for skin testing cattle for bovine tuberculosis. This new standard creates a global organized system to ensure uniform testing worldwide. These findings will benefit regulatory agencies, veterinarians, and livestock producers involved with maintaining the tuberculosis-free status for the United States. (NP103, C3, PS3c, Project No. 5030-32000-222-00D)

Venereal transmission of vesicular stomatitis virus in biting midges. Biting midges are well-known agricultural pests that transmit vesicular stomatitis virus (VSV) to cattle, horses, and swine. Vesicular stomatitis outbreaks occur every 3–8 years in the United States and result in significant economic losses due to animal disease, animal movement restrictions, and quarantines. In temperate regions, viruses appear to overwinter in the absence of infected animals through unknown mechanisms, resulting in new infections the following year. ARS scientists in Manhattan, KS, collaborated with Kansas State University to examine whether VSV could pass between male and female midges during mating to better understand whether virus may be maintained in insect populations in multi-year outbreaks. They found that during mating, VSV-infected females could transmit virus to uninfected naïve males that had never been exposed to the virus, and that infected males could transmit virus to uninfected naïve females. This research shows the importance of males in VSV transmission dynamics, and the role vectors may play in the maintenance of VSV. This is the first evidence for venereal transmission of any arbovirus (viruses that infect arthropods) in biting midges, and the first evidence for venereal transmission of VSV in any known vector species. These results highlight the need to incorporate alternative routes of transmission in understanding arbovirus outbreaks, and could lead to a more comprehensive understanding of: (1) potential virus persistence in nature between outbreaks; (2) the

ability of some virus strains to survive through the winter leading to multi-year outbreaks; and (3) virus transmission dynamics during VSV outbreaks. (NP103, C1, PS1b, Project No. 3020-32000-013-00D)

Duration of contagion of foot-and-mouth disease virus in infected live pigs and carcasses. Data-driven modeling of high-consequence foreign animal disease outbreaks is a critical component of veterinary preparedness. However, research and data are needed to address knowledge gaps in disease dynamics and modeling. ARS scientists in Orient Point, NY, conducted a study to address two major gaps in knowledge of foot-and-mouth disease virus (FMDV) pathogenesis in pigs: (1) the duration of the infectious period; and (2) the viability of FMDV in decaying carcasses. ARS scientists demonstrated that infected pigs transmitted disease at 10 days post infection (dpi), but not at 15 dpi. Assuming a latent period of 1 day, this results in a conservative estimate of 9 days infectious duration, which is considerably longer than suggested by previous research conducted with cattle. The residual airborne contagion diminished within 2 days of removal of infected pigs from isolation rooms. Furthermore, FMDV in muscle was inactivated within 7 days in carcasses stored at 4˚C. By contrast, FMDV infectivity in vesicles harvested from intact carcasses stored under similar conditions remained remarkably high until the study termination at 11 weeks post-mortem. This information may be used to update models used for FMD outbreak simulations involving areas of substantial pig production and emphasizes that infected carcasses can be a potential source of virus contamination and must be handled properly to prevent FMDV transmission. (NP103, C1, C1a, Project No. 8064-32000-061-00D)

Performance of a brucellosis diagnostic test in domestic and wildlife species. Billions of dollars have been invested at State and Federal levels to eradicate brucellosis from the United States. Brucellosis is a

bacterial disease largely controlled in domesticated livestock, but it has been very difficult to eradicate because of reinfection from wildlife reservoirs such as bison, elk, and feral swine. It is a zoonotic disease that can spread from cattle to people and cause severe human illness. The fluorescence polarization assay (FPA) is a highly sensitive and specific test commonly used for brucellosis surveillance under field conditions. Although designed for use in cattle, the test is also used for surveillance in elk, swine, and bison using negative control cattle sera included in the kit. ARS scientists in Ames, IA, tested sera from non-infected swine, bison, and elk against sera from control, vaccinated, and Brucella-infected animals to determine if species differences could influence responses to the test. The data demonstrate the assay results are influenced by the species of background sera, which is important for surveillance studies and regulatory agencies. Some species' sera were incorrectly interpreted as positive for brucellosis. Additionally, the assay does not perform as well in swine and did not detect animals persistently infected with the *Brucella abortus* strain RB51 vaccine. This work will be of interest to regulatory personnel in States with brucellosis-infected wildlife, those conducting surveillance studies, and livestock producers. (NP103, C3, PS3a, Project No. 5030-32000-224-00D)

A computational method to quantify the effects of genome replication errors on bacterial evolution. Bovine respiratory disease costs the industry hundreds of millions of dollars each year through treatment costs and losses in production. Bovine respiratory disease is often caused by a complex of viruses and bacteria. Researchers do not understand how some bacteria normally found in the respiratory tract can suddenly become virulent. ARS researchers in Clay Center, NE, developed a novel method to study how bacterial respiratory pathogens such *as Mannhemia haemolytica, Histophilus somni,* and *Bibersteinia trehalosi* suddenly become virulent. These bacteria all possess genomic features

consisting of a single base or multiple bases, repeated in series, called simple sequence repeats (SSRs). These SSRs allow the bacterial genes to change rapidly through replication errors that occur during DNA synthesis. Sometimes the change is great and alters the appearance, virulence, or pathogenicity of the bacterium and is referred to as phase variation. Developing methodology to track these replication errors will greatly increase the ability to understand how different bacteria cause disease and advance the development of mitigation strategies. (NP103, C4, PS4a, Project No. 3040-32000-034-00D)

Effect of environmental temperature on the ability of mosquitoes to transmit Rift Valley fever virus. ARS researchers in Manhattan, KS, and collaborators at the U.S. Army Medical Research Institute for Infectious Diseases evaluated how environmental temperature affects the ability of two mosquito species native to the United States to transmit Rift Valley fever virus (RVFV). Mosquito incubation temperatures ranging from 14˚C to 26˚C were evaluated for their effect on virus infection, dissemination, and transmission rates. For both mosquito species tested, increased temperature was associated with more rapid and more efficient infections and increased the potential for mosquitoes to transmit RVFV. Although environmental temperature affected the ability of RVFV to replicate and amplify in mosquitoes, the effect differed between the two species. The results indicated that the effect of temperature on RVFV dissemination and transmission was species dependent. These data on the effects of ambient temperature facilitate development of more accurate models to assess RVFV persistence and spread in nature should a disease outbreak ever occur in the United States. (NP103, C1, PS1b, Project No. 3020-32000-009-00D)

Characterization of a new strain of bovine viral diarrhea virus isolated in the United States. A new bovine viral diarrhea virus (BVDV) strain was isolated in California. While belonging to the BVDV1 grouping of BVDV viruses, it does not belong to the BVDV1a or BVDV1b groups that are known to be in the United States. Characterizing this virus is important to determine the effectiveness of current bovine vaccines to protect against emerging BVDV viruses. ARS scientists in Ames, IA, in collaboration with researchers at the University of California, Davis, revealed this virus was a novel BVDV1 strain, now called BVDV1i, that had not been previously reported in the United States. Genetic analysis of the virus sequence showed this virus had only been reported in Europe and South America. Further tests were conducted using antibodies raised against BVDV strains found in commercial bovine vaccines and results indicated these antibodies recognized the BVDV1i strain but at a reduced level, so current vaccines may only provide partial protection against emerging BVDV1. (NP103, C4, PS4a, Project No. 5030-32000-117-00D)

The first U.S. national survey of *Mycoplasma ovis* in domestic sheep operations. *Mycoplasma ovis* is a blood pathogen in sheep, goats, and deer. While its presence has been documented in the United States, there had been no large-scale study documenting its prevalence and geographic range among sheep. ARS researchers in Pullman, WA, in collaboration with researchers at the USDA Animal and Plant Health Inspection Service, performed the first national survey of *M. ovis* in U.S. sheep. Samples were collected from more than 34,000 U.S. sheep as part of the National Animal Health Monitoring Surveys, and *M. ovis* was present in 73.3 percent of U.S. sheep operations. Furthermore, when present, *M. ovis* occurred in 23.3 percent of sampled individuals within the flock. These data demonstrate *M. ovis*

is more common than previously believed in the United States and may contribute to anemia, jaundice, and ill-thrift (failure to thrive) for many sheep. (NP103, C4, PS4d, Project No. 2090-32000-036-00D)

Genomic regions of *Streptococcus suis* reveal differences that may contribute to the spectrum of clinical disease. Different bacterial isolates of *S. suis* cause a spectrum of disease in pigs which complicates studies to understand how the bacterium causes disease. ARS researchers at Ames, IA, evaluated the ability of nine isolates of *S. suis* to cause disease following intranasal challenge in swine. This was followed by comparative genomic analyses to identify genetic differences in the isolates potentially associated with swine virulence. Challenge outcomes ranged from lethal systemic disease to no signs of disease. Whole genome sequencing followed by comparative genomic analyses revealed several notable regions of difference, including regions encoding secreted and membrane-associated factors, which likely contributed to the spectrum of clinical disease observed. In addition, transmissible elements containing antimicrobial resistance genes were identified within the *S. suis* genomes. Collectively, these results provide a foundation for understanding the genomic attributes responsible for the spectrum of virulence that exists among *S. suis* isolates. This information is essential for designing effective vaccines needed by the swine industry to mitigate *S. suis* disease and reduce public health concerns. (NP 103, C4, PS4b, Project No. 5030-32000-119-00D)

Attractant-impregnated sticky film for stable fly mass trapping. Stable flies feed on livestock and cause significant animal stress and loss of vigor. This leads to production losses, increased susceptibility to disease, and sometimes death. They are also a nuisance pest of domestic pets, zoo animals, and humans in some U.S. coastal areas. Current stable fly control methods are ineffective and too costly.

ARS scientists in Lincoln, NE, in conjunction with an industry partner, developed an attractant-impregnated adhesive tape for mass trapping stable flies. The traps can reduce stable fly-induced stress and defensive behaviors of confined cattle by up to 80 percent, and result in improved cattle weight gain and milk production. This technology also has potential for reducing stable flies on pets, zoo animals, and on humans in coastal communities. An international patent was granted on this technology. (NP104, C1, PS1B, Project No. 3042-32000-011-00D)

Treated military uniform compromised by pesticide-resistant mosquitoes. Military camouflage uniforms are routinely treated with permethrin to repel disease-carrying mosquitoes. This preserves an effective fighting force while military members operate in environments where mosquito-vectored diseases are endemic. ARS researchers in Gainesville, FL, and U.S. Department of Defense collaborating scientists completed and published a study clearly demonstrating that treated military uniform efficacy may be completely compromised by pyrethroid-resistant strains of *Aedes aegypti*, a vector of numerous human diseases. Fortunately, this study also showed that the protection provided by N,N-Diethyl-meta-toluamide (DEET)-based repellents was unaffected by resistance to pyrethroids. This information will aid in the risk assessment of different operational environments and lead to changes in procedures and chemicals used to protect at-risk military members operating in areas where pyrethroid-resistant mosquitoes exist. (NP104, C2, PS2A, Project No. 6036-32000-052-00D)

Discovery of synergists for topical and spatial repellents that circumvent pesticide-resistant mosquitoes. Pyrethroids are one of the most commonly used classes of insecticides. The acids of three common pyrethroids were shown to be nontoxic to mosquitoes. ARS researchers in Gainesville, FL,

along with partners at the University of Florida, discovered these pyrethroid acids have significant synergistic spatial repellent activity. Synergists are compounds that, when added to a pesticide or repellent, greatly increase the efficacy or repellency over the pesticide or repellent alone. The repellency measured was greater than the topical repellent N,N-Diethyl-meta-toluamide (DEET), was often better than the parent pyrethroids, and showed little cross resistance in a pyrethroid-resistant Puerto Rico strain of mosquitoes. Most important, synergism caused by the pyrethroid acids, when combined with several repellent compounds, increased protection of human arms from biting mosquitoes. Using these synergists may increase bite protection for existing and novel compounds, including protection against resistant mosquitoes that can transmit diseases such as dengue, Zika, chikungunya, and yellow fever. (NP104, C2, PS2A, Project No. 6036-32000-052-00D)

House flies collected in agricultural settings carry antimicrobial-resistant bacteria. House flies are primary pests of confined livestock operations such as dairies; due to their close associations with humans, they are nuisance pests in domestic settings. Adult flies frequent microbe-rich substrates such as garbage dumpsters and animal manure, where they encounter and ingest bacteria during feeding and reproduction. To assess human and animal health risks, bacteria were enumerated from whole flies, identified to species, and tested for susceptibility to 14 antimicrobials. Both male and female flies carried antimicrobial-resistant (AMR) bacteria: 36 of 38 isolates (95 percent) were resistant to more than one antimicrobial, 33 were multidrug-resistant (MDR); and 24 isolates were resistant to more than 4 antimicrobials. These results emphasize the role flies may play in harboring and disseminating bacteria, including AMR and MDR strains and potential pathogens that pose a risk to human and animal health.

The results add to the growing evidence implicating flies as major players in disease ecology, epidemiology, and the dispersal of AMR genes. (NP104, C1, PS1C, Project No. 3020-32000-018-00D)

House flies carry and can potentially transmit bacterial pathogens associated with bovine respiratory disease. House flies are major nuisance pests at feedlots and are of concern to animal health since they acquire, harbor, and transmit numerous pathogens. Bovine respiratory disease (BRD) is an economically important and complex illness of cattle associated with several bacterial and viral species. It is not clear what role flies play in harboring and transmitting bacterial pathogens associated with BRD. ARS scientists in Manhattan, KS, collected house flies from a commercial feedlot where cattle were suffering from apparent respiratory illness. Two different methods were used to examine the prevalence of the three main BRD bacterial pathogens *Mannheimia haemolytica, Pasteurella multocida,* and *Histophilus somni* in male and female flies. Using both methods, *M. haemolytica* was detected in 11.7 percent of house flies, followed by *P. multocida* (5 percent) and *H. somni* (3.3 percent). The presence of BRD bacterial pathogens in house flies suggests they can play a role as reservoirs and disseminators of the bacteria in the feedlot environment. Further, infected flies pose a risk transmitting BRD when they acquire pathogens from sick animals and subsequently associate with healthy animals. (NP104, C1, PS1C, Project No. 3020-32000-018-00D)

Novel insecticide shows promise for fly pests of livestock. Heavy reliance on chemical control resulted in widespread resistance to almost all available marketed pesticides for filth and biting flies. ARS researchers in Gainesville, FL, and Kerrville, TX, and researchers at Northern Illinois University, The Pennsylvania State University, and Cornell University evaluated the effectiveness of the novel

insecticide fluralaner against house flies and horn flies resistant to two commonly used insecticides, imidacloprid and permethrin. When fed to flies in sugar bait, fluralaner was 23-fold more toxic to a susceptible house fly strain than imidacloprid and more than 117-fold more toxic to an imidacloprid-resistant house fly strain. It also out-performed permethrin when applied directly to the flies. At present, fluralaner is only registered for use on dogs and cats for flea control. These results indicate this material would be very useful against insecticide-resistant flies. (NP104, C1, PS1C, Project No. 6036-32000-053-00D and 3094-32000-041-00D)

Toxicity of chitosan for house flies, horse flies, and blow flies. House flies, horse flies, and blow flies are important pests of humans and their associated animals. ARS scientists in Gainesville, FL, and researchers at the University of Massachusetts examined insecticidal properties of chitosan, a polysaccharide derived from chitin. Chitosan fed to adult house flies (*Musca domestica*), horse flies (*Tabanus nigrovittatus*), and blow flies (*Phormia regina*), was found to be toxic to all three. Chitosan appears to disrupt the microorganisms that live in the gut of the fly. It is easily made, commercially produced, non-toxic to mammals, biodegradable, and used in a range of agricultural applications. Chitosan shows promise as a new environmentally friendly pesticide against filth and biting flies affecting humans and livestock. (NP104, C1, PS1C, Project No. 6036-32000-053-00D)

Natural compounds as insecticides and fly repellents. Fly resistance to chemical pesticides is an increasing problem and highlights the need to develop alternatives to existing fly control chemical pesticides. ARS scientists in Kerrville, TX, demonstrated the effectiveness of a number of natural compounds, including essential oils and other botanical compounds, as repellents or insecticides in

laboratory bioassays against various life stages of horn flies. Cinnamon oil, spearmint oil, citronellol, and limonene each exhibited repellent activity comparable or greater than N, N-Diethyl-meta-toluamide (DEET) to horn flies. Unlike DEET, these natural plant compounds also exhibited insecticidal activity against horn flies. These compounds can be incorporated into integrated pest management strategies to suppress horn fly populations associated with livestock production, reducing losses to livestock producers and potential annoyance to nearby human populations. (NP104, C1, PS1C, Project No. 3094-32000-041-00D)

Virus infection makes flies lose their appetite. Previous studies have shown that Musca domestica salivary gland hypertrophy virus (MdSGHV) dramatically enlarges salivary glands and prevents or delays ovarian development in its adult host, the common housefly, and could potentially be used as a biocontrol method. The effect of the virus on the fly's natural food consumption, however, remained unexplored prior to this study, which was conducted by ARS scientists in Gainesville, FL, and researchers at the University of Massachusetts. Both virus-infected and control flies were provided a choice of an 8-percent sucrose solution or a 4-percent powdered milk solution to determine food preferences. Healthy females with developing ovaries continued to consume a sugar and protein diet while infected females fed predominantly on a sugar diet. Infected flies of both sexes consumed less food than healthy flies. Infected flies in the field may spend less time visiting food sources, which could reduce their survival and the risk of human pathogen movement. (NP104, C1, PS1C, Project No. 6036-32000-053-00D)

***Beauveria bassiana* is only effective against house fly larvae during a brief time window.** Using entomopathogenic fungi such as *Beauveria bassiana* to manage adult house fly populations shows promising results, but little is known about whether it can be used against house fly larvae. ARS researchers in Gainesville, FL, demonstrated that temperature and diet did not modify the effectiveness of *B. bassiana* treatments against fly larvae. Additional testing revealed fly larvae are only susceptible to the pathogen when they are very young, and very high fungal doses are required to kill them. The results show that *B. bassiana* can control adult flies effectively but that larval control with this biocontrol agent is prohibitively expensive. (NP104, C1, PS1C, Project No. 6036-32000-053-00D)

Natural spread of a virus in imported fire ants. Introduced from South America, the red imported fire ant currently infests more than 128 million hectares of land in the United States and is estimated to cause damage exceeding $7 billion annually. *Solenopsis invicta* virus 3 (SINV-3) is an RNA virus specific for red imported fire ants that offers promise as a natural control agent. It infects queens and immature ants and results in a colony weight reduction of more than 50 percent. ARS scientists in Gainesville, FL, and researchers at Florida A&M University conducted surveys to determine the prevalence of SINV-3 in winged female fire ants to understand the possible natural spread of the virus through mating flights. Collections were made from five urban areas and five adjacent north Florida rural areas. SINV-3 was detected in winged females in nests from 7 of the 10 collection locations. The average infection rate of 44 percent was similar in rural and urban areas. Winged females were sampled because they mate aerially and disperse, founding colonies in new areas. Infected winged females may be the mechanism of SINV-3 spread throughout the fire ant community and may provide additional sustained control of fire ants in the United States. (NP104, C3, PS3C, Project No. 6036-32000-051-00D)

A super colony of invasive ants in Florida. The tawny crazy ant is an invasive ant from South America that infests Florida and Texas and is spreading to States along the Gulf Coast. Extremely large populations of this ant inundate urban and natural landscapes, resulting in mass intrusions into buildings as well as reductions in ant biodiversity. ARS researchers in Gainesville, FL, determined that tawny crazy ants did not fight with other tawny crazy ants from different nests located at the same site, or with ants from nests located as far as 270 miles away. In fact, small fragments of colonies from distant nests, including queens, congregated together in the same nests in laboratory tests. Tawny crazy ants are not territorial over large areas. These findings suggest that tawny crazy ants in Florida are part of a super colony across the southern United States and that the lack of territorial behavior facilitates resource sharing and the movement of worker ants and brood between colonies. These characteristics could be used in developing control strategies, including the spread of natural enemies such as pathogens and toxic baits being developed for their control. (NP104, C3, PS3B, Project No. 20196036-32000-051-00D)

Development of a rapid resistance assay to aid in mosquito control. Pyrethroids have been used in the control of mosquitoes for years. Due to their heavy use, many populations of mosquitoes became resistant to various pyrethroids. Rapid detection of resistance allows for the proper pesticide selection for mosquito abatement. ARS researchers in Gainesville, FL, and collaborating scientists at the U.S. Department of Defense developed a novel, rapid assay for assessment of pyrethroid resistance in the southern house mosquito, *Culex quinquefasciatus*. This assay is quick, inexpensive, and fits within existing assay systems for several species of mosquitoes. The assay is currently being tested in a Florida study and will soon be implemented in Louisiana. (NP104, C2, PS2A, Project No. 6036-32000-052-00D)

New and quick method to identify fever ticks resistant to pyrethroids. Cattle fever ticks were eradicated from the southeastern United States but continue to reinfest parts of southern Texas. The presence of wildlife complicates eradication efforts by spreading ticks across the Mexico-United States border into Texas. Pyrethroids are a class of pesticide used to control tick infestations on cattle in Mexico and on U.S. wildlife. However, many tick populations in Mexico are resistant to pyrethroids. Quick and accurate diagnosis of pyrethroid resistance in the cattle fever tick is critical for selecting the appropriate pesticide to use. ARS scientists in Kerrville and Edinburg, TX, and Pullman, WA, worked with collaborators at Northern Arizona University and the University of Queretaro (Mexico) to develop a new and quick method to identify fever ticks resistant to pyrethroids. This assay can detect multiple changes in the gene coding for the protein targeted by pyrethroids and which can lead to resistance. This molecular assay can be completed overnight while the traditional bioassay method takes 6 weeks to complete. The ability to quickly detect pyrethroid-resistant ticks allows decision makers to choose the proper pesticide to use on wildlife during Texas outbreaks. (NP104, C1, PS1A, Project No. 3094-32000-042-00D)

Release of the 'Delta' Select strain of channel catfish. Improved catfish germplasm in aquaculture will reduce production costs and allow U.S. catfish farmers to remain competitive in the global seafood market. ARS researchers in Stoneville, MS, developed the 'Delta Select' strain of channel catfish through three generations of genetic selection, leading to a 25-percent increase in growth rate and 0.9 percent increase in carcass yield compared to the non-selected Delta Control line that originated from the same population. Since fillet yield is somewhere around 45 percent, changes of even 1 (of the 350 million pounds of fish harvested annually) would result in a big difference (3.5 million pounds).

Approximately 90,000 head (180,000 pounds) of 2-year-old 'Delta Select' catfish were released to industry, providing U.S. farmers access to improved catfish germplasm that will make them more efficient and profitable. (NP106, C1 PS1B, Project No. 6066-31000-016-00D)

Genome-enabled breeding tools for Atlantic salmon. The number of U.S. commercial Atlantic salmon farming operations is expected to increase 5-fold over the next 3 years, and demand for genetically improved stocks will increase dramatically. ARS researchers in Franklin, ME, and Leetown, WV, created an improved genome reference sequence for the North American Atlantic salmon and developed the first DNA chip that enables the use of genomic information in breeding strategies. This DNA chip is publicly available and in use by commercial breeding programs. (NP106, C2, PS2A, Project No. 8030-31000-005-00D)

A rapid assay for *Flavobacterium columnare.* Columnaris disease is caused by the bacterium *Flavobacterium columnare* and negatively impacts almost all finfish aquaculture industries in the United States and worldwide. Previous research established the existence of four distinct genetic groups within the species *F. columnare*; however, there were no quick and easy methods to assign an unknown isolate to one of the four groups. Knowing which group is causing outbreaks informs decisions on how to respond. ARS researchers in Auburn, AL, developed a molecular assay to quickly assign an isolate to a genetic group, demonstrating the assay is rapid, sensitive, and specific for genotyping *F. columnare*. The assay is inexpensive and can be used by any laboratory with basic molecular capabilities to determine the genetic group(s) responsible for disease outbreaks. It is currently used by commercial and academic laboratories. (NP106, C1 PS1B, Project No. 6010-32000-027-00D)

An alternative aquafeed protein source improves growth and immune responses. Frass is a byproduct of the fly larval meal industry and is composed of larval excrement, shed exoskeletons, and residual fly feed. ARS researchers in Auburn, AL, evaluated diets containing black soldier fly frass as partial replacements for soybean meal, wheat short (the fine bran particles, germ, and particles separated in commercial flour milling), and corn meal. Experimental diets were fed to fingerling catfish and tilapia and the results demonstrated that final weight gain was significantly increased. Additionally, tilapia fed frass diets exhibited increased survival against two important pathogens, *Flavobacterium columnare* and *Streptococcus iniae*. Based on these findings, frass derived from the larvae of black solder flies has potential as an alternative source of protein in aquafeeds or as an ingredient enhancing palatability and growth. (NP106, C1, PS1A, Project No. 6010-32000-027-00D)

Pyranopyrans are potential bacteriocidal compounds against fish pathogens. Disease losses in catfish aquaculture can cost up to $100 million, so reducing or eliminating bacterial pathogens is critical to the success of the industry and improving fish health and welfare. ARS researchers in Oxford, MS; Stoneville, MS; and Villanova University modified the chemical structures of natural compounds produced by a certain species of fungus to produce novel compounds. The novel compounds pyranopyrans possess significant antibacterial activities against certain species of fish pathogens. Combatting disease with alternative efficacious natural or natural-based compounds is very acceptable to the catfish industry, which has access to only a few approved therapeutants and is striving to limit the use of antibiotics. (NP106, C1, PS1B, Project No. 6066-31000-016-00D)

A bacteriophage for preventing disease in rainbow trout. Bacteriophages (phages) are viruses that infect and kill bacteria, self-replicating in high numbers in the process. Used against disease-causing microbes, phages are excellent candidates for the prevention or treatment of bacterial diseases. ARS researchers in Leetown, WV, identified a new phage that kills *Yersinia ruckeri,* the rainbow trout

pathogen. This phage is unique; in addition to killing its bacterial host by infection, it also binds to and degrades lipopolysaccharide, a large carbohydrate structure that covers the surface of some bacteria and reduces the effectiveness of the trout immune system. By trimming off this protective layer, the phage renders *Yersinia ruckeri* susceptible to the trout immune system, preventing its survival inside its fish host. (NP106, C2, PS2B, Project No. 8082-32000-007-00D)

Improved method to measure starch content and gelatinization. Starch is an important component of various food and feed products. Starch gelatinization (DGS) is important during processing starch-containing foods or feeds; the degree of DSG affects physiochemical and sensory properties of starchy products and their susceptibility to enzymatic digestion and so affects their nutritional availability for humans or animals. ARS researchers in Hagerman, ID, recently developed an improved method for simpler and more accurate measurement of total starch and gelatinized starch in situ for wet and dried products. This provides a valuable new tool for food and feed researchers to study the role of starch in food and feed products. (NP106, C2, PS2A, Project No. 2050-21310-006-00D)

A draft genome sequence for Florida pompano. The lack of available genome information is a hurdle in implementing state-of-the-art selective breeding strategies for many aquaculture species, including

Florida pompano. ARS-funded researchers in Fort Pierce, FL, established a complete draft genome of the Florida pompano by using a hybrid sequencing method and a novel bioinformatics workflow. This draft genome will improve farm production and profitability and enhance breeding strategies by identifying genes associated with aquaculture production efficiency and product quality. (NP106, C5, PS5A, Project No. 6034-22000-044-00D)

Catfish diets and feeding strategies affect meat yield. During the production and harvest cycle, catfish farmers are sometimes unable to sell and must hold market weight catfish for processing if there is a lack of demand. Feeding fish during this holding time allows the fish to grow larger than the preferred size for processing. If feed is withheld during this time, the fish mobilize muscle tissue for energy, reducing fillet yield. In either case, the price paid to farmers is reduced. ARS researchers in Stoneville, MS, worked in cooperation with Mississippi State University fish nutritionists and determined that hybrid catfish fed once or twice weekly for 4 months remained in the preferred size range for processing but had reduced fillet yield. Thirty days of full feeding were needed to restore fillet yield to normal levels in fish fed once or twice weekly for 4 months. These results allow the catfish farming industry to develop feeding strategies that minimize production costs and maximize profits. (NP106, C1, PS1B, Project No. 6066-31000-016-00D)

Nutritional requirements of Florida pompano broodstock. Quality broodstock diets increase reproductive success and seedstock quality, leading to increased hatchery success, on-farm efficiencies, and profitability. The lack of optimal diets for Florida pompano broodstock (especially during the spawning season) continues to present an obstacle to commercial production, because nutritional status

is a powerful determinant of egg quality and the successful development of eggs and larvae. ARS-funded researchers in Fort Pierce, FL, employed comprehensive and quantitative lipid analysis to determine different egg and larval lipid compositions and identify lipid requirements for larval development and successful reproduction of Florida pompano. Hatchery managers and marine finfish producers will benefit from efficiencies associated with meeting optimum nutritional needs for reproduction and successful seedstock production. (NP106, C5, PS5A, Project No. 6034-22000-044-00D)

NATURAL RESOURCES AND SUSTAINABLE AGRICULTURAL SYSTEMS

National Programs:

- **Water Availability and Watershed Management, NP 211**
- **Soil and Air, NP 212**
- **Grass, Forage and Rangeland Systems, NP 215**
- **Sustainable Agricultural Systems Research, NP 216**

A long-term solution for thirsty crops. A cost-effective means of increasing plant-available water can alleviate water stress from infrequent precipitation or limited irrigation supplies. Polymer hydrogels increase the capacity of soil to hold water, but the effects were previously thought to last only a few years. ARS researchers in Kimberly, ID, conducted a 9-year study to measure the effects of a single hydrogel application on plant-available water in soil. Based on the slow decline in water availability seen in this study, the water retention benefits of hydrogels should last from 24 years to 29 years, considerably longer than current industry estimates. The long-term water retention benefits substantially increase the cost effectiveness for farmers applying hydrogels to improve soil's water holding capacity. (NP211, C3, PS B, Project No. 054-13000-009-00D)

Deficit irrigation saves water in peach production under arid conditions. Agricultural irrigation is a major user of fresh water in arid and semiarid areas of the world. About 23,000 hectares of peaches grown in the Central Valley of California depend on irrigation, which uses scarce water resources. Deficit irrigation is a potential strategy to save water without severely impacting crop production; however, the long-term impact of deficit irrigation on productivity is not well understood. ARS researchers in Parlier, CA, demonstrated in a 10-year field study that deficit irrigation can result in up to 40 percent water savings without significant yield losses or reductions in fruit quality such as firmness, total soluble solids, pH, malic acid, or total phenolics. Findings from this long-term research provide peach growers an alternative irrigation strategy to save water and lower input costs. (NP211, C1, PSA, Project No. 2034-13000-012-00D)

Center pivot mounted leaf temperature sensors are inexpensive and provide accurate input to irrigation water optimization. In times of low crop prices, farmers need to produce crops as inexpensively as possible. One way farmers can reduce input costs is to irrigate only when it is most needed. Crop leaf temperatures are easily measured by sensors, which provide a real-time assessment of water stress and in turn indicate if irrigation should be scheduled. However, users of temperature sensors have been concerned that measurements from sensors mounted on a center pivot may not be as accurate as non-moving (stationary) sensors. ARS scientists in Bushland, TX, compared irrigation scheduling based on data from stationary temperature sensors to those mounted on a center pivot. There were no differences in accuracy between stationary or moving temperature sensors, and irrigation application scheduling governed by one type of sensor was similar to scheduling governed by the other. Center pivots are now used on 30 million acres in the United States. Installing temperature sensors aboard

center pivots and using them for irrigation scheduling could save farmers substantial water and reduce energy input costs. (NP211, C1, PSA, Project No. 3090-13000-015-00D)

New water budgets across the Long-Term Agroecosystem Research (LTAR) network. Management of intensified agricultural production and climate can affect soil water storage and water movement in agricultural landscapes. Understanding these relationships is critical to more efficient and sustainable water use. ARS scientists in Columbia, MO, along with collaborators at all 18 LTAR sites, have developed agricultural site water budgets that account for all inputs and outputs of water on an average annual basis. The LTAR network covers a wide range of values for yearly precipitation, evaporation, plant water uptake, surface runoff, and subsurface flow. The LTAR modeling group is using these water budgets to validate their models across the network. (NP211, C4, PSA, Project No. 5070-12130-006-00D)

Alternative crops grown in saline soils provide value-added products. Drought-, salt-, and boron-tolerant plant species that are adapted to grow with high saline drainage or ground waters in poor-quality soils are valuable commodities in the western United States. ARS researchers in Parlier, CA, are testing the viability of several specialty crops in saline drainage sediment and in saline/boron soils in the San Joaquin Valley. They are irrigating salt- and boron-tolerant poplar-tree clones, Opuntia cactus, guayule, mustard, agretti, and pistachio with drainage waters containing high levels of salt, boron, and selenium. All tested plants and trees produced selenium-enriched plant products, and guayule produced increased amounts of latex and resin under saline conditions. The successful use of alternative drought-, salt-, and boron-tolerant crops and the production of new biobased products provide growers new agronomic

strategies and alternative crops for continuing production in drainage-impacted regions of the western Central Valley of California. (NP211, C1 PSF, Project No. 2034-13000-012-00D)

Modified blind inlets structure design improves dissolved phosphorus removal. Blind inlets, which are limestone-gravel filters for agricultural drainage water in field depressions, were shown to be effective at reducing losses of particulate phosphorous (P) (i.e., P bound to sediment) by virtue of sediment filtration. However, typical blind inlets are ineffective at removing dissolved P, which is a greater water quality hazard than particulate P. ARS scientists in West Lafayette, IN, improved a blind inlet by constructing it with steel slag, a material that has a high affinity for dissolved P, and monitoring for impact on water quality. Over a 3-year period, the use of steel slag removed 45 percent of the dissolved P, 18 percent of the organic nitrogen, 67 percent of the ammonium, and 70 percent of the glyphosate and dicamba from field runoff. Steel slag costs for blind inlets are similar to the costs of aggregates and provide a simple update for improving removal of dissolved P and some pesticides. The benefit to growers is that it reduces their negative impact on water quality and increases production sustainability by preventing the loss of nutrients and pesticides. (NP211, C2 PSD, Project No. 5020-12130-003-00D)

Soil and leaf sensors improve irrigation scheduling for water conservation. Because of limited water resources on the Texas High Plains, producers are interested in growing grain sorghum, which requires less water than corn to produce maximum yields. However, precision irrigation scheduling tools are needed to optimize regional sorghum production. ARS scientists in Bushland, TX, in collaboration with the Rural Development Administration of South Korea and the University of Nevada at Reno, have used

automated irrigation scheduling based on leaf canopy temperature with and without data from soil moisture sensors to manage grain sorghum at high, medium, and low irrigation levels. The scientists found that plant and soil water sensing with multiple stress thresholds and several different irrigation volumes led to the most water efficient irrigation management for grain sorghum producers in Texas. The methods achieving the highest water use efficiency were readily automated. Irrigators implementing such a system will save time, use less energy, and reduce groundwater withdrawals. (NP211, C1, PSA, Project No. 3090-13000-015-00D)

Sub-surface drip reduces seasonal irrigation applications for corn. In the face of declining water supplies, crop farmers need to maximize the yield per unit of water used in crop production, the so-called crop water productivity (CWP). It is not well understood how irrigation application methods affect CWP. ARS scientists in Bushland, TX, compared the water use and yield of grain corn and sorghum production using sprinkler and subsurface drip irrigation (SDI) methods. Using the SDI application method, loss of water to evaporation was reduced by 2-5 inches during the growing season, compared to losses that occurred with sprinkler irrigation. SDI reduced overall corn water use by up to 6 inches and increased grain yields by up to 20 percent. The combined effects were an increase in CWP by up to 46 percent, compared with sprinkler irrigation. The increases in CWP are enough to offset the higher costs for SDI installation. (NP211, C1, PSC, Project No. 3090-13000-015-00D)

Effective nitrate removal from tile drained fields in Iowa using saturated riparian buffers. The saturated riparian buffer is a conservation practice that diverts agricultural tile drainage into streamside soils, which can effectively remove nitrate from drainage water at little cost. Conservation planners want

to understand the potential role of this practice in addressing nitrate losses from agricultural watersheds with tile drained cropland. ARS scientists in Ames, IA, applied the Agricultural Conservation Planning Framework (ACPF) in 32 Iowa watersheds to determine the extent of riparian zones suited for saturated buffers, and the extent of tile drained lands found above those same riparian zones. Riparian lengths suited to the saturated buffer practice occupied 30-70 percent of streambanks in most watersheds and could treat tile drainage from 15 to 40 percent of the watershed areas. Saturated buffers have an important potential role for water quality improvement in many tile-drained watersheds in Iowa and to a lesser extent where riparian practice options are limited. These results are useful for conservation planners seeking to identify viable options to reduce nitrate loads from Midwestern agricultural watersheds. (NP211, C3, PSA, Project No. 5030-13000-011-00D)

Terrestrial sources of urea shown to contribute more than urea fertilizer to toxic algal blooms. Global increases in the frequency and toxicity of algal blooms in coastal waters are raising concerns over agricultural use of urea, the most common form of commercial nitrogen (N) fertilizer. ARS researchers in University Park, PA, with colleagues from the University of Maryland-Eastern Shore and Penn State University, evaluated urea transport in field drainage, runoff, and stream water within an agricultural basin on Maryland's Atlantic Coastal Plain. Results showed that runoff of recently applied urea in early spring is usually diluted below levels of environmental concern. However, in summer, stagnant water in small field ditches and wetlands creates ideal conditions for microbial production of urea that flushes into local streams and subsequently flows to coastal waters. Producers can manage drainage control structures to allow ditches to drain freely during summer. This will minimize the development of stagnant water pools, which will greatly reduce the risk of harmful algal blooms due to

urea flushing from agricultural drainage ditches into streams and coastal waters. (NP211, C2, PSA, Project No. 8070-13000-014-00D)

Legume cover crop impacts on sugarcane production. Sugarcane is a commercially important crop in Louisiana, Florida, and Texas, and the sugar produced is worth over $1 billion (U.S.) annually. However, monoculture sugarcane production can degrade soils by reducing soil organic matter and enabling soil pathogenic microorganism proliferation. Cultural practices that improve sugarcane sustainability are thus needed to maintain yields in fields with degraded soils. Legumes can be grown to improve soil health during the normal fallow period between sugarcane crops. ARS scientists in Houma, LA, in collaboration with scientists at Louisiana State University AgCenter and Alma Plantation, completed multi-year and location trials that investigated how sunn hemp and cowpea cover crops affected subsequent sugarcane yields. On average, the cover crops provided 4.3 tons per acre of dry biomass and 200 pounds per acre of nitrogen. Cowpea generally improved subsequent plant cane yields, but the effects of sunn hemp varied. However, neither cowpea nor sunn hemp reduced cane or sucrose yields consistently in subsequent sugarcane crops. Legume cover crops can be an important component of sustainable sugarcane production practices and are now being used by growers in several parishes in Louisiana. (NP211, C4, PSC, Project No. 6052-13210-002-00D)

Mapping of manure sheds helps improve manure nutrient utilization and the environment. Nutrient recycling is fundamental to sustainable agricultural systems. Few mechanisms exist, however, to ensure that surplus manure nutrients from confined animal feeding operations (CAFOs) are effectively transported for use in nutrient-deficient croplands. These nutrients sometimes concentrate in

locations where they can threaten environmental health and devalue manure as a fertilizer. As part of the Long-Term Agroecosystem Research (LTAR) effort, an ARS team from multiple locations, led by scientists in Las Cruces, NM, classified the 3,109 counties of the contiguous United States by their capacity to either supply manure phosphorus (P) and nitrogen (N) or assimilate and remove excess P and N via crops ("sinks"). ARS scientists in St. Paul, MN, assisted in the analysis and are co-leading a follow-up effort focusing on the dairy component of manure production and use. Manure sheds—areas surrounding livestock operations where excess manure nutrients can be recycled for agricultural production—differed in the transport distances needed to assimilate excess manure P based upon the type of CAFO (from 147 ± 51 km for a beef-dominated manure shed to 368 ± 140 km for a poultry-dominated manure shed). This highlighted the need for systems-level strategies that operate across local, county, regional, and national scales to promote manure nutrient recycling. This LTAR approach is now being applied to each animal segment (dairy, hog, beef, poultry) at the national level to close the loop between animal manure production and plant nutrient needs, which will reduce contamination of ground and surface waters in animal production regions. (NP211, C2, PSD, Project No. 5062-12130-007-00D)

Semiarid grassland nitrous oxide emissions increase with warmer temperatures. Although much climate change research focuses on carbon dioxide, there are other important greenhouse gases occurring in smaller quantities, but with greater potency than carbon dioxide, including nitrous oxide (N_2O). ARS researchers in Tucson, AZ, and colleagues from China analyzed 46 published studies worldwide in which temperature or precipitation were artificially altered to test for effects on N_2O emissions. They found that increased temperature drove increased N_2O release from soils by an average of 33 percent, although the results varied across biomes, with the biggest response in shrublands.

Increased precipitation also enhanced N_2O emissions, while reduced precipitation suppressed emissions. Collectively, these results suggest that globally warming temperatures may increase N_2O release, representing a reinforcing effect on climate change in the future. (NP211, C2, PSB, Project No. 2022-13610-012-00D)

Long-term dataset demonstrates value of native cover in protecting water quality. Long-term research is important to understanding how land management affects runoff and erosion in agricultural production systems. ARS scientists have compiled, discussed, and published 23 years of historical data measured in eight fields located in El Reno, OK. Results indicated that native tallgrass prairie fields had 98 percent, 72 percent, and 78 percent lower suspended sediments, total soluble phosphorus, and nitrate-nitrogen losses, respectively, than cropped fields. This research database is essential for determining the impact of different agricultural management systems, understanding the processes related to hydrologic transport and water quality, and the development and validation of the corresponding models. These data contribute to national initiatives, including the Long-Term Agroecosystem Research network and the Conservation Effects Assessment Project, that are working to quantify the effects of land management on soil and water resources under variable climate. (NP211, C2, PSA, Project No. 3070-13000-012-00D)

Late planted corn requires less irrigation water. Because of declining water levels in the Southern Ogallala Aquifer region, alternative management strategies are needed to reduce groundwater withdrawals while maintaining profitable crop yields. Delayed planting of corn on the Texas High Plains is believed to reduce irrigation requirements by taking advantage of increased precipitation and reduced

evapotranspiration demand. However, limited field data exist for corn planting dates in the region. ARS researchers at Bushland, TX, and Texas A&M AgriLife used a calibrated Soil Water Assessment Tool (SWAT) model with long-term historical climate data to simulate corn irrigation and yields for both long and short season corn varieties. Simulation results suggested that irrigation requirements of short season corn were at least 25 percent lower than requirements for long season corn, while grain yields decreased by less than 9 percent. Data from field experiments conducted in 2016 and 2017 with drought tolerant corn hybrids corroborated these trends. These results indicate that the delayed planting of corn combined with effective irrigation management have the potential to reduce groundwater withdrawals from the Ogallala Aquifer. These results are useful to irrigators as a means of extending their groundwater resources and reducing their energy input costs. (NP211, C1, PSA, Project No. 3090-13000-015-00D)

Adaptive nutrient management demonstrates enhanced economic and environmental outcomes. With increasing variability in climatic and economic drivers, producers who have previously used static agricultural management strategies may want to pursue adaptive management principles to improve net returns and potentially other ecosystem services. ARS researchers at Temple, TX, managed cropped fields in the Riesel Watersheds for 16 years using 0-8 tons of poultry litter per acre for their annual application rates. During this period, management progressed from static management to adaptive management using the Haney Soil Health Test, which reduced nitrogen (N) application rates in fields with poultry litter applications and recommended cover crops. Using adaptive nutrient management reduced N application rates by 25 to 38 percent for low rates of poultry litter without sacrificing profitability. Poultry litter application rates in excess of crop phosphorus demand increased phosphorus

runoff losses while reducing profitability. Long-term studies that analyze field-scale agronomic, economic, and environmental factors are extremely rare, since they are expensive and labor intensive. This LTAR study shows producers, conservation professionals, and policy makers the utility of adaptive management principles over the longterm as one potential suite of practices to balance economic and environmental outcomes through agronomic management. (NP211, C4, PSA, Project No. 3098-13610-008-00D)

Method for partitioning deisopropylatrazine in streams. Streams within the Salt River Basin of northeastern Missouri are chronically contaminated with the triazine herbicides atrazine and simazine and their common metabolite deisopropylatrazine (DIA). However, in order to link stream pesticide levels to herbicides applied in the fields, one needs to know the parent source of DIA. Therefore, a method is needed to partition DIA between its two parent sources – i.e., DIA derived from atrazine (DIAATR) and DIA derived from simazine (DIASIM). ARS scientists in Columbia, MO, along with University of Missouri cooperators, developed a method based on the concentration ratios of simazine to atrazine (SAR) in streams. The SAR method performed better than two other methods based on concentrations of chloro-triazines in field runoff. The SAR method results demonstrated the differences in DIASIM and DIAATR transport timing, with peak DIASIM transport occurring from mid-November to April and peak DIAATR transport from May to June. In the Salt River Basin, dual-season triazine applications substantially increased the period of high chloro-triazine concentrations in streams from approximately 3 to 8 months per year. This new method provides water resources and conservation managers the means to identify the parent herbicide and target conservation efforts toward its management in order to improve water quality. (NP211, C2, PSA, Project No. 5070-12130-006-00D)

Assessing RUSLE2 and WEPP differences as a conservation planning tool. To streamline delivery of conservation assistance to farmers, the USDA Natural Resources Conservation Service (NRCS) plans to transition from the Revised Universal Soil Loss Equation 2 (RUSLE2) to the Water Erosion Prediction Project (WEPP) to guide conservation planning regarding erosion by water. However, there are concerns that estimated erosion rates may increase as a result of the transition, thereby adversely impacting farmers' conservation compliance. ARS researchers in Oxford, MS (RUSLE2 Team), and West Lafayette, IN (WEPP Team), conducted almost 40,000 simulations covering different climate, soil, land management, terrain, and crop yield conditions for counties in Illinois and Iowa. The soil loss estimates for about half of the simulation scenarios were statistically different between RUSLE2 and WEPP. In comparable scenarios, the primary differences were related to model soil erodibility characterization, slope length effects, no-till management, and cover crop managements. WEPP was sensitive to the quality of climate inputs, so future work should include comprehensive evaluations of different climate scenarios, as well as data precision, gaps, and resolution. The performed assessment is vital to conservation management planning provided by NRCS and farmers' conservation compliance under specific provisions of the 2018 Farm Bill. (NP211, C3, PSA, Project No. 6060-13000-026-00D)

A new modeling approach for soil and gully erosion research. A new 2D numerical simulation model has been developed by ARS researchers in Oxford, MS, to simulate soil erosion and gully erosion processes in field-sized watersheds. This physically based model mimics rainstorm-induced watershed runoff, splash erosion, shear erosion of soil, and sediment transport processes in high resolution. The simulation results were validated using experimental and field observation results collected by Federal agencies. This new capability helps hydrology and agriculture engineers in erosion control research and

provides the NRCS a powerful tool (http://websim.rusle2.org), that will help evaluate ephemeral erosion throughout the country. (NP211, C3, PSA, Project No. 6060-13000-028-00D)

Strategic management using new and improved decision tools can improve farm productivity and environmental impacts. Producers and researchers need decision-making tools to estimate how their production decisions influence farm productivity and environmental impacts. ARS researchers in Fort Collins, CO, collaborated with Colorado State University to upgrade the DayCent model, and with American Farmland Trust (AFT) to develop the CaRPE tool. ARS researchers improved DayCent by accounting for soil freeze-thaw effects on nitrous oxide (N_2O) emissions, representing soil organic matter dynamics to 30-cm depths, addressing how cover crops and their removal affect greenhouse gas (GHG) emissions, and a range of other management factors. These changes increased the accuracy of GHG emissions modelling, which in turn produced more accurate GHG emissions that were 22 percent higher from 1990 to 2017 relative to the previous inventory. The COMET-Farm tool imbeds algorithms from the DayCent model and is frequently used for field and farm productivity and GHG estimation. It provides much of the modeling power of the CaRPE tool, an interactive management tool that couples crop and grazing land data from the NASS Ag Census with county-level GHG emission-reduction coefficients from COMET. CaRPE has been used to explore the regional and national potential for agriculture to reduce GHG emissions and combat climate change, and AFT testified about its impacts before the House Select Committee on the Climate Crisis. These tools will enhance the ability of farmers to manage their systems, provide better estimates of and strategies to control GHG emissions, and provide a better foundation for additional scientific discoveries and agricultural management. The tools are useful to producers, NGOs such as the AFT and The Nature Conservancy, and Government

organizations, including NRCS, EPA, and NOAA. (NP212, C1, PS1A, PS1B, C2, PS2A, Project No. 3012-11120-001-00D)

Phenol accumulation in California rice soils correlates with late-season inhibition of crop nitrogen uptake. A key factor of rice grain yield is late-season crop uptake of soil nitrogen (N), which promotes grain filling. Previous ARS research in experimental rice plots in Arkansas indicated that inhibition of late-season crop N uptake was correlated with soil levels of phenol, which at higher levels can inhibit N uptake. Recently, ARS researchers in Ames, IA, collaborated with the University of California, Davis to analyze soil from fields on working farms in the Sacramento Valley that varied widely in late-season rice uptake of N. Soil phenol concentrations were moderately correlated with late-season rice N uptake, providing first-time, on-farm evidence to strengthen the previous ARS findings from Arkansas. Variation in soil phenol content may be caused by differences in how fields are aerated during the season. The basis for increased soil aeration arose partially from ARS rice research in Arkansas and is now being studied in additional rice-producing States in the United States. The practice of increased soil aeration has also been incorporated into the Sustainable Rice Platform (http://www.sustainablerice.org/), which is a global organization composed of more than 100 institutional members. It is striving to improve rice management practices of 1 million small farmers worldwide. (NP212, C2, PS2A, Project No. 5030-12000-015-00D)

Precision agriculture has a new tool for creating soil carbon content maps. Soil carbon mapping is extremely useful in assessing how land management practices affect and promote crop productivity, agroecosystem sustainability, and ecosystem services. ARS researchers in Auburn, AL, have developed

a unique mobile system that uses neutron-gamma analysis to assess and map soil carbon to a depth of 30 cm (plow layer) in real-time. The team coupled their mobile system to a Global Positioning System device to simultaneously acquire soil carbon content and geographical positions for field mapping. The reliability of soil carbon measurements was found to align well with traditional soil sampling, well within the 95-percent prediction bands. The approach yields an efficient, geo-referenced tool to facilitate rapid, inexpensive, and accurate construction of soil carbon maps. This methodology is licensed for commercialization and will be useful to all crop producers, the national and global soil health community, such as NRCS and the UN FAO Global Soil Partnership, and university researchers and NGOs. It has potential applications for other soil assessment needs in the areas of construction and land restoration for the BLM and even the DOD. (NP212, C1, PS1A, PS1B, Project No. 6010-11120-008-00D)

Standardizing soil analysis provides an understanding of the soil microbiome and its relationship to soil health. Soil health is a complex concept that requires fundamental characterization of the living soil ecosystem. There is a critical need for reliable and consistent scientific methods (such as microbiome analysis that depends on advanced DNA methods) to do that characterization. Standardizing protocols for sample collection, sample handling, laboratory analysis, and data collection and analysis is critical to reduce study variability, improve interpretation of results, and increase the use of soil health assessments for developing better soil health management for productivity, sustainability, or resilience to climate change. A consortium of ARS scientists in Pendleton, OR; Fort Collins, CO; Brooking, SD; Riverside, CA; Columbia, MO; Fayetteville, AR; Florence, SC; Beltsville, MD; Lincoln, NE; Stoneville, MS; and Morris, MN, developed such a protocol to address sources of variability and uncertainty in

measuring microbial community composition and its connection with agricultural management and changing climate. Success in these areas is essential for deriving a "return on investment" for managers considering a shift to soil health-promoting practices. The tools and data are important to the soil health community in the United States, the global community (e.g., the UN FAO Global Soil Partnership), and researchers from public and private institutions worldwide who are interested in applying information on the genetic potential of soil to enhance soil ecosystem sustainability. (NP212, C1, PS1A, PS1B, PS1C, Project No. 0500-00034-001-00D)

New agriculturally focused collection of *E. coli* types for enhanced animal and food safety. *Escherichia coli* (*E. coli*) is a bacterial species commonly isolated from humans and animals as an indicator of fecal contamination of water supplies and environments, and more than 700 types (e.g., serotypes) of *E. coli* have been identified. Although most *E. coli* serotypes found in animal production are harmless, they are shown to be a source and reservoir for antibiotic resistance genes that may be transferred to animal or human pathogens. This antibiotic resistance is a significant concern for the health of producers, their animals, and the public at large, so understanding their differences will help in identification and mitigation strategies. Most *E. coli* collections focus on human health, and very few collections represent the genetic variability and virulence of those affecting U.S. food animal production. ARS researchers in Florence, SC, led the assembly of AgEc, a publicly available collection that identified and studied 300 *E. coli* variants found in four major animal production commodities – beef, dairy, poultry, and swine. This was a collaborative effort of 15 researchers from 9 ARS research units, universities, and NRCS partners, and addressed production systems across 12 States. The team tested the collection serotypes for resistance genes to two common antibiotics, tetracycline and

sulfonamide, and analysis of antibiotic resistance gene patterns revealed significant differences along commodity and geographical lines. This AgEc effort provides a new publicly available database useful to producers and food- and animal-inspection communities about the types and distribution of *E. coli* antibiotic resistance in animal production farms. It will assist in determining sources of fecal contaminants in water systems, food, and environments. (NP212, C3, PS3A, Project No. 6082-12630-001-00D)

Stacking management practices improves soil health. Linking specific management practices to measurable changes in soil properties is a key objective for increasing adoption of those practices to improve soil health. ARS scientists in Brookings, SD, used two long-term field studies to show how adding or stacking new practices to base management can affect soil structure and microbial activity. Both studies had base management that included no-till. In one study, crop rotation diversity was added as a new practice, and in the second study, crop residue retention and cover cropping were added. Changes in the extent to which added managements changed soil properties often depended on at what point samples were taken during the crop rotation, showing that stacking management is not simply additive. However, no negative effects were observed from stacking soil health building practices to the no-till crop systems. Implementing multiple positive management tactics increases the likelihood that improvements in soil properties related to better health can be measured. This information is valuable to scientists researching related topics, extension personnel advising producers, and producers selecting management tactics as part of their strategy to increase their ecosystem services. (NP212, C1, PS1B, Project No. 3080-12620-005-00D)

Groundwater quality in Upper Midwest is affected by human and dairy pollutants. The groundwater aquifer in northeast Wisconsin is vulnerable to contamination because it has thin overlying soils that allow contaminants from the land surface to move rapidly to the water table. Because of these conditions, wastewater from septic systems and livestock manure from farming operations are possible contaminant sources for nearby wells. ARS researchers in Marshfield, WI, found up to 28 percent of private wells in Kewaunee County, WI, had detectable coliform bacteria (an indication of fecal contamination) or nitrate-N concentrations greater than 10 mg/L. Furthermore, pathogens that can cause human illness were found in private wells and both human wastewater and cattle manure were identified as sources of the fecal contamination in the contaminated wells. The researchers also tested 964 samples from 145 wells supplying public water systems in Minnesota and found that fecal contamination was present in 58 percent of samples and 96 percent of wells. They also found that simple tests used by public water systems for bacteria indicative of fecal contamination were good at predicting pathogen absence, but not pathogen presence, and would not be reliable for estimating illnesses from drinking fecal-contaminated groundwater. These findings are providing opportunities for communities in the region to understand the extent of water contamination by human and animal pathogens and for improving groundwater quality for residents. (NP212, C3, PS3A, Project No. 5090-12630-005-00D)

New poultry manure amendments reduce environmental impacts. Ammonia gas emissions from poultry houses and phosphorus (P) loss in runoff from fields where litter (manure + bedding) is applied are two environmental problems from poultry production. Because spreading alum in poultry houses reduces both these problems and improves bird health, the practice is used for about 40 percent of the broiler chickens in the United States. Recently, however, adding alum has not reliably reduced litter-

soluble P as much as in the past. In fact, adding alum increased soluble P in litter that had been treated with sodium bisulfate, a popular ammonia-control product. ARS researchers in Fayetteville, AR, discovered that adding small amounts of calcium-based nanoparticles to litter treated with alum and/or poultry litter treatment caused a synergistic reaction that resulted in very low soluble P. The researchers also found that treating litter with alum mud, which is a byproduct remaining after alum manufacture, reduced ammonia emissions from poultry litter an average of 40 percent, which was not significantly different from the 35-percent reduction in emissions from alum alone. This presents a sustainable use for the alum mud byproduct, which is currently being landfilled at a cost of $32 per ton. These combined practices of using alum, nanoparticles, and alum mud could be applied to 80 percent of broiler production facilities in the United States to improve bird health and reduce environmental impacts. (NP212 C3 PS3B Project # 6022-63000-005-00D)

Enhancing crop yields with beneficial crop symbionts. ARS researchers in Wyndmoor, PA, developed molecular tools to identify, quantify, and characterize 11 species of agriculturally relevant arbuscular mycorrhizal fungi (AMF) to enable the selection of the most beneficial AMF for crops. This team previously developed methods for on-farm production of mixed-species AMF inoculum, which, when applied to seedlings, increased yield of several crops (including strawberries, tomatoes, eggplant, peppers, potatoes, and leeks). However, it was not possible to measure or determine how AMF affected individual species. The team then developed quantitative PCR (qPCR) detection assays for 11 different species of AMF found in agricultural soils. These assays identified and quantified the fungi directly from soil samples and in plant root tissues, enabling spore enumeration from soil samples within a single workday, compared to the previous assessment approach that took more than a month to complete. The

qPCR method enables direct measurement of individual AMF species colonization efficiency on plant roots, which was not previously possible, and provides an indication of which AMF species are likely to have the most beneficial impacts on crop productivity. These advanced tools will improve agricultural sustainability by guiding the selection of AMF species for propagation and development as AMF biofertilizers—products that improve nutrient acquisition and water uptake and reduce susceptibility to pathogens and disease. (NP212, C1, PS1A, PS1B, PS1C; C2, PS2A, PS2B, Project No. 8072-12000-013-00D)

New method rapidly quantifies field spatial overlaps and gaps for precision agriculture tools. Auto-guided tractors can reduce on-farm inputs by as much as 20 percent and nationally save producers $10.8-13.5 million each year by improving equipment efficiency and enhancing yields. Lowering fertilizer and herbicide applications can reduce potential losses to the environment. About half of large-scale crop producers are using tractor guidance, but 82 percent of U.S. farms are small farms that are largely not adopting these cost-saving and environmentally sound technologies. ARS researchers in Fayetteville and Booneville, AR, in collaboration with the University of Arkansas, developed a novel automated method to rapidly determine spatial overlaps (up to 6 percent of the total field area) and gaps (up to 16 percent of field area) in machinery coverage, and how much precision technologies, such as auto-guided tractors and other self-propelled machinery, can reduce those overlaps and gaps. Tractor guidance systems during field operations improve the average overall efficiency by 8 percent, reducing input use and in-field operation time. This novel approach of estimating tractor guidance efficiency on small farms can aid in adoption of tractor guidance, potentially improving efficiency gains on 82 percent of U.S. farms. (NP212, C3, PS3C, Project No. 6022-63000-005-00D

New economical and efficient strategies remove antibiotics from wastewater and increase agricultural safety and human health. Understanding the removal mechanism of antibiotic compounds and antibiotic resistance determinants in agricultural systems is a global challenge that is important in the protection of human health. An ARS researcher from Riverside, CA, and collaborator from University of California, Riverside, designed and tested a layered environmental media system (consisting of gravel, sand, soil, and a "soil plus biochar" combination) through which antibiotic-laden water was pumped. Overall removal efficiencies of four tested antibiotics—amoxicillin, cefalexin, sulfadiazine, and tetracycline—were 81, 91, 51, and 98 percent, respectively. If the exposure time was lengthened, the removal efficiency was increased, especially for amoxicillin and cefalexin. Overall, the results from this lab-scale proof of concept system indicate the potential of the system for antibiotic removal from wastewater and highlight ways in which removal efficacy improvements may be scalable for broad applicability. The results of this study will be used by wastewater treatment facilities, the World Health Organization, researchers, and other local municipalities in many developing countries. (NP212, C3, PS3A, Project No. 2036-32000-005-00D)

New research targets less enteric methane emissions from cattle. Cattle produce the greenhouse gas methane as a natural byproduct of digestion, and researchers are investigating ways to help reduce these enteric methane emissions. ARS scientists from Bushland, TX; Woodward, OK; and El Reno, OK, in collaboration with Texas A&M AgriLife Research, studied how cattle methane emissions were affected by hay nutritional quality and fiber content. Cattle fed a high-quality hay diet (high crude protein) produced less methane per unit of digested organic matter than when fed low-quality hay. ARS researchers at Bushland, TX, and Ames, IA, also showed that adding tannin-rich peanut skin, a common

regional byproduct, to cattle diets can suppress rumen microbial methanogenesis. This research shows scientists and producers the multiple benefits of feeding higher quality hay to improve animal performance and reduce emissions and indicates the feed additives that may provide cost-effective mitigation of enteric methane from beef and dairy cattle. (NP212, C3, PS3B, Project No. 3090-31630-005-00D

Conservation tillage rebuilds surface soil organic carbon and nitrogen content. Conservation tillage is an effective management strategy to rebuild soil organic carbon and total nitrogen levels. However, there are few long-term studies available to quantify either the rate of change or measurable benefits. ARS researchers in Florence, SC, created a long-term tillage and crop management experiment using sandy soils. Topsoil samples were collected annually over 37 years under conservation and conventional tillage, and organic carbon and total nitrogen content were measured. Topsoil under conservation tillage had 23 percent more organic carbon and 16 percent more total nitrogen than topsoil under conventional tillage. Furthermore, both tillage systems seem to have reached a new equilibrium where total organic carbon is no longer increasing. These unique results obtained over nearly 4 decades will help landowners and greenhouse gas technical assistance providers determine the climate value and amount of carbon credits from implementing conservation tillage practices under new USDA carbon credit programs. (NP212, C1, PS1B, Project No. 6082-12630-001-00D)

Pulverized wastepaper helps rehabilitate military training lands. The United States Army produces a significant amount of classified paper waste that is pulverized to a fine consistency unsuitable for recycling. However, this cheap, high-quality organic material can be useful as a soil amendment. ARS

researchers in Auburn, AL, worked with the U.S. Army Corps of Engineers to develop technology that uses pulverized wastepaper to rehabilitate military training lands. Application of paper waste to soils had no adverse environmental effects, improved soil physiochemical properties, and improved the establishment of desirable native vegetation. When combining cost savings associated with landfill disposal of the paper with savings from greater land rehabilitation success, every ton of diverted paper saves an estimated $300. At the recommended application rate, this results in a cost savings of approximately $4,700 per acre. At the installation level, this equates to an estimated annual costs savings of $20,000 and the diversion of 70 tons of paper. (NP212, C3, PS3D, Project No. 6010-11120-008-00D)

Strategies to reduce the causes of nitrous oxide emissions from beef cattle feed yards. Nitrous oxide is a potent greenhouse gas linked to climate change. Elevated nutrient concentrations make livestock manure a source for nitrous oxide production. Scientists from Bushland, TX; Clay Center, NE; and Texas A&M AgriLife Research investigated how weather affected nitrous oxide emissions from commercial beef cattle feed yards. They determined that nitrous oxide emissions were greatest under warm temperatures and shortly after rainfall events. The team determined that producers and regulatory personnel could manage these emissions more effectively when they can better couple weather patterns with animal agriculture's weather-mediated nitrous oxide emissions. The researchers also developed an empirical model to assess the effect of manure removal frequency on annual nitrous oxide emissions as related to these conditions. These data and tools in development will be useful for updating national greenhouse gas emissions inventories for beef cattle feed yards. In addition, the cost of managing on-farm nutrients can be improved for increased manure value, which is an important bottom line for producers. (NP212, C2, PS2A, C3, PS3B, Project No. 3090-31630-005-00D)

Alfalfa leaf protein concentrate is a sustainable alternative to fish meal for aquaculture diets. Aquaculture is the production of fish and shellfish in controlled conditions and is the fastest growing food sector worldwide. However, fishmeal used in diets of most aquaculture species is a limited, unsustainable resource with volatile pricing. To determine if alfalfa could be a source of protein for use in aquaculture, ARS scientists in Saint Paul, MN, and collaborators from the University of Minnesota pressed fresh alfalfa foliage to produce a juice and then concentrated the proteins by various methods. A heat treatment resulted in a protein concentrate with the most favorable amino acid profile that did not contain antinutritional factors commonly found in proteins from other plant sources like seed meals. Feeding studies with yellow perch and rainbow trout found that both species accepted alfalfa protein concentrate in feeds. Approximately 800 pounds of protein concentrate can be produced from an acre of alfalfa, and the remaining plant residue can be used as a feed ingredient for cattle, or as a bioenergy feed stock. This research on alfalfa protein concentrate provides the aquaculture industry with the promising development of a sustainable alternative to fishmeal in diets and the alfalfa production industry with a new, high-value use for their crops. (NP215, C4, PS4C, Project No. 5062-12210-003-00D)

AlkarXL, a new tall wheatgrass cultivar for use on saline, semiarid lands. With urban spread in the western United States, farmers and ranchers rely increasingly on marginally productive soils that are frequently high in salt to produce forage. Tall wheatgrass is one of the most salt tolerant grasses used for fall and winter livestock grazing on dryland salty soils, but the yield and quality of this forage for livestock production needed improvement. ARS scientists in Logan, UT, in collaboration with seed companies, developed and released ‘AlkarXL’, a new tall wheatgrass cultivar with better forage quality for use on saline soils. Across multiple locations, years, and harvests, AlkarXL produced 3.02 tons per

acre of forage, which was on average 14 percent greater than five other common tall wheatgrass cultivars. AlkarXL's protein content of 6.2 percent after harvest in the summer was 11 percent greater than these other cultivars. AlkarXL also had higher protein in the fall after regrowth (12.8 percent) than these cultivars and was well above the 7 percent protein level needed by grazing ruminant livestock. Seed of AlkarXL is now commercially available, providing an improved forage grass for marginal salty rangelands. (NP215, C2, PS2A, Project No. 2080-21000-018-00D)

Grass-Cast: A new decision-support tool helps livestock producers improve productivity from rangelands. Western U.S. livestock producers on rangelands can best manage their operations when they use flexible stocking strategies to match the forage needs of their animals with the forage availability on their land. Because forage growth varies greatly depending on precipitation, producers need ways to predict how much forage will be available to take advantage of flexible stocking strategies. ARS scientists from Cheyenne, WY, and Fort Collins, CO, in collaboration with Colorado State University, the University of Arizona, and the National Drought Mitigation Center, developed Grass-Cast, a grassland productivity forecasting tool. Grass-Cast uses year-to-date climate data and seasonal precipitation outlooks to forecast forage production for rangelands at the 6 x 6-mile spatial resolution. Grass-Cast was publicly released in 2018 for the Northern Plains, in 2019 for the entire Great Plains, and in 2020 for New Mexico and Arizona. The public release included the co-development of a new website (https://grasscast.unl.edu), which was recently expanded in 2020 and is co-managed by the USDA Northern Plains Climate Hub and the National Drought Mitigation Center at the University of Nebraska. Grass-Cast has garnered widespread media coverage at regional and national levels, including a USDA official press release, blog posts, radio news stories, and stories in agricultural newspapers and

websites. Livestock producers are interested in having Grass-Cast expanded to the Great Basin, California, and even Canadian prairies. (NP215, C3, PS3B, Project No. 3012-21610-003-00D)

Early alfalfa establishment in silage corn can increase dairy farm profitability. Corn and alfalfa are major crops grown in rotation on dairy farms in the United States. The same alfalfa crop lasts several years, but the conventional practice of planting alfalfa in the spring after a corn crop results in lower yields and farm profitability the first year because the alfalfa is not fully established. ARS and University of Wisconsin scientists in Madison, WI, developed an alternative system where alfalfa is established a year earlier by interseeding into corn. This results in full alfalfa production the following year. The scientists recently used crop yield data, estimated feed values, and farm production costs to show the benefits of the new interseeding alfalfa production system. It can increase net returns by about 15 percent compared to the conventional spring-seeded alfalfa system. The early alfalfa establishment also improves forage yields and provides cover crop benefits for protecting soil and water resources. Dairy farmers will be able to use this new crop production approach to increase their economic and environmental sustainability. (NP215, C4, PS4C, Project No. 5090-12210-001-00D)

Managing Midwest dairy forage production systems to maintain soil carbon. The U.S. dairy industry is committed to environmental stewardship goals, including neutral or reduced carbon emission from dairy farms. Research is needed to determine the opportunities on farms to reduce carbon emissions and sequester carbon, including soil carbon storage. ARS researchers in Saint Paul, MN, monitored carbon balances for 9 years on three fields on a large dairy that uses both solid-liquid separation and anaerobic digestion for manure management. Under the current alfalfa-corn silage

production with conventional tillage and inputs of liquid dairy manure, the field soils were losing carbon, with losses more than three times greater under corn silage than alfalfa. To maintain a neutral carbon balance in corn silage, the equivalent of 70 percent of the carbon removed in harvested corn would have to be returned to fields. That value is 30 percent for alfalfa. However, returned carbon should be even greater to have net soil carbon storage. This rate of carbon returns to fields may require changes in tillage, crop rotation, and manure management, all of which may be a challenge given how such changes affect other enterprises on the farm. These results are being used by scientists developing decision-aid tools that can evaluate whole-farm carbon uses and balances, by dairy producers to understand the tradeoffs in their carbon management, and by dairy industry stakeholders supporting carbon sustainability goals. (NP215, C1, PS1A, Project No. 5062-12210-003-00D)

Development of genomic tools to identify gastrointestinal parasite resistant sheep. Perhaps the most important means of parasite control is an animal's natural resistance. Genetic resistance to parasitic nematodes varies among individual animals within a breed and is moderately heritable. The ability to identify genetic markers of animal resistance to parasites will have wide benefit in the sheep industry as parasites become increasingly resistant to dewormer treatments. A team led by ARS researchers in Booneville, AR, used identified gene DNA sequence variation that was associated with resistance to gastrointestinal parasites in sheep. The team is funded by NIFA's Organic Agriculture Research and Extension Initiative and included colleagues from Louisiana State University, Virginia Tech, Katahdin Hair Sheep International, University of Nebraska-Lincoln, and University of Idaho. This information is important to producers, scientists, veterinarians, and extension specialists to increase natural parasite

resistance in sheep and to reduce the use of dewormers, which can in turn reduce parasite resistance to dewormers and extend their effectiveness. (NP215, C4, PS4B, Project No. 6020-21310-011-00D)

Mixing alfalfa and birdsfoot trefoil into tall fescue pastures can improve growth performance and economic return of beef cattle. High nitrogen fertilizer costs and increased emphasis on environmental stewardship have renewed interest among beef producers in the western United States in integrating legumes into their high-productivity, irrigated pastures. However, these producers need to know how forage and livestock growth on grass-legume mixtures compare to that on conventional grass-only pastures fertilized with nitrogen. ARS researchers in Logan, UT, measured herbage mass, nutritive value, steer growth performance, and economics of tall fescue pastures mixed with alfalfa or birdsfoot trefoil compared to fescue-only pastures with nitrogen fertilizer. The grass-legume mixed pastures had slightly less herbage, but nutrition and steer growth performance were better than with fertilized grass pastures. Without the added cost of fertilizer, economic returns for the grass-legume pastures were 2.4 (trefoil) and 1.7 (alfalfa) times greater than the fertilized grass pastures and were competitive with many other crops grown in the region. These novel grass-legume mixtures can help U.S. beef farmers increase the forage and livestock productivity of their pastures and rangelands while reducing dependence on petroleum-based commercial fertilizer. (NP215, C4, PS4B, Project No. 2080-21000-018-00D)

Genes associated with *Verticillium* wilt resistance in alfalfa are identified. *Verticillium* wilt is an alfalfa disease that reduces forage yields by up to 50 percent. An ARS scientist in Prosser, WA, identified DNA sequence changes in two different alfalfa genes that were reliably associated with resistance to *Verticillium* wilt and accounted for one-third of the variation in resistance to the disease.

Based on these results, a rapid polymerase chain reaction (PCR) test was developed that may help identify alfalfa plants with increased resistance based on genetic differences. The PCR assay is being further validated in commercial populations. If successful, this new test will accelerate the development of improved alfalfa varieties by making it easier for breeders to select for substantial changes in resistance to *Verticillium* wilt. (NP215, C2, PS2A, Project No. 2090-21000-036-00D)

Determining plant properties and management practices that improve rangeland restoration after wildfire. Grasses are critical plants used in seeding rangeland in the western United States for restoration after wildfire and where invasive species threaten ecosystem function. These rangelands vary widely through the year in soil temperature and moisture conditions that affect grass seedling establishment, and grasses vary inherently in how well they establish. ARS researchers in Boise, ID; Burns, OR; Fort Collins, CO; and Woodward, OK; along with collaborators at the University of California, found that seeds planted later in the fall have a much higher chance of surviving winter mortality, and that diversifying the seed mix is key to ensuring that at least some seedlings successfully establish. ARS researchers in Logan, UT, examined the effect of soil water on root and shoot growth of seven grass species. Three species increased both root and shoot biomass in response to water, while four other grasses increased shoot growth but not root growth. They also found that higher seed mass produced seedlings with more shoot and root biomass that favors short-term growth, while less seed mass produced seedlings with greater surface area of leaves and roots that is better for long-term growth. These findings can improve successful seedling establishment by public land management agencies, help develop more recalcitrant native grass species, and match grass populations to specific site

conditions—all to improve re-seeding efforts and make western rangelands more fire and weed resistant. (NP215, C1, PS1A, Project No. 2080-21000-018-00D and No. 2052-13610-014-00D)

Napier grass (elephant grass) as a bioenergy feedstock. Napier grass has the highest biomass productivity of any grass for cropping in the southeastern United States, but management practices to optimize its use in the production of bioethanol are needed. Over a 5-year period, ARS researchers in Tifton, GA, and Peoria, IL, compared how harvest management affected bioethanol production. If the crop was fertilized in May and harvested once per year in December, production was consistent over 5 years. The ethanol yield per acre using one harvest per year was 962 gallons in the second growing season and 1,368 gallons in the fourth season, which out-yields the national average yield of 180 bu/525 gallons from corn produced for ethanol. In contrast, two harvests per year (June and December) led to dramatic declines in production beginning in Year 3. This work will help bioethanol producers and farmers in the Southeast maximize Napier grass as a competitive bioethanol feedstock. (NP215, C4, PS4C, Project No. 6048-21000-030-00D)

Use of noninvasive sampling procedures can help diagnose livestock exposure to poisonous plants. Larkspurs, lupines, and death camas can be acutely toxic to livestock and are serious poisonous plant problems in western North America. Poisoning of livestock by plants often goes undiagnosed because there is a lack of appropriate or available specimens for analysis. ARS researchers in Logan, UT, developed procedures to detect toxic compounds in easily obtainable animal samples (rumen contents, ocular fluid, earwax, hair, oral fluid, and nasal mucus) to help easily diagnose cattle that consumed toxic plants. The advantage of using theses samples is that collecting them is noninvasive and relatively

easy—no special equipment is required, and untrained personnel can easily collect the samples. These methods will be valuable for livestock producers, extension agents, veterinarians, and especially laboratories to help diagnose animals that are poisoned by common toxic plants found in rangeland environments. (NP215, C4, PS4D, Project No. 2080-32630-014-00D)

Survey of pollinating insects in centipedegrass lawns. In the United States, turfgrasses are a major component of the landscape and cover more than 40 million acres. Centipedegrass is a warm-season turfgrass that is often grown in the southeastern United States. Recently, honeybees were documented collecting pollen from the flower structures of centipedegrass. To understand the role of turf species such as centipedegrass in supporting pollinators, ARS researchers in Tifton, GA, and scientists from the University of Georgia surveyed bees in centipedegrass lawns in central and southern Georgia. Numerous bees were observed, of which 79 percent were Lasioglossum species (sweat bees). Minor species observed included long-horned bees; other species of sweat bees, including metallic green sweat bees; bumble bees; leafcutter bees; and small carpenter bees. These data indicate that diverse bees are residing in or near lawns and forage in and around the lawns seeking centipedegrass flowers. The knowledge that many bees are present in centipedegrass lawns indicates that homeowners and landscape managers should apply insecticides conservatively, since certain insecticides are toxic to foraging bees in lawns. (NP215, C1, PS1A, Project No.6048-21000-030-00D)

Evidence of consistent and sustained profitability in precision agriculture cropping systems. Targeting management practices and inputs with precision agriculture has high potential to meet some of the grand challenges of sustainability in the coming century. The benefits include improving crop

profitability and reducing environmental impacts, but its reputation for high cost limits its popularity. To better understand long-term effects of precision agriculture on crop profitability, ARS scientists in the Columbia, MO, Long-Term Agroecosystem Research (LTAR) network site monitored a 90-acre field in central Missouri for over a decade under conventional management (1993–2003) and then for another decade under a precision agriculture system (2004–2014). Conventional management was a corn-soybean rotation, annual tillage, and uniform fertilizer and herbicide inputs. Key aspects of the precision system were no-tillage, cover crops, winter wheat instead of corn on areas with shallow topsoil and low corn profitability, and variable-rate fertilizer (nitrogen, phosphorus, potassium, and lime) applications. Results indicated that precision agriculture sustained profits in 97 percent of the field without subsidies for cover crops or payments for enhanced environmental protection. In a separate study, ARS scientists in Pendleton, OR, applied a specialized mathematical model to multiple years of yield map data from a dryland field in South Dakota (corn-soybean rotation) and an irrigated field in Georgia (corn, soybean, and peanut). In both cropping systems, this analysis method effectively revealed patterns of productive and unproductive parts of the field. This information can be used to target more efficient crop management techniques, and these results help growers gain confidence in the economic success of precision agriculture management and conservation practices. (NP 216, C1, PS1D, Project No. 5070-12610-005-00D and Project No. 2074-12210-001-00D.)

Long-term data show crop diversity improves corn yields and enhances drought resilience. ARS researchers in Akron, CO; Lincoln, NE; Brookings, SD; and Beltsville, MD, in collaboration with scientists from universities across North America, compiled 347 seasons of data from 11 long-term experiments that spanned the continental precipitation gradient. Researchers found that more diverse

crop rotations increase corn grain yield across all growing conditions by an average of 28 percent and that during drought years, corn yield losses were reduced from 14 to 90 percent. Crop rotation diversification is a risk-reduction strategy for producers under increasingly stressful weather conditions. (NP216, C1, PS1A, Project No. 3010-12210-004-00D, Project No. 3042-11210-003-00D, Project No. 8042-21660-005-00D and Project No. 3080-12620-005-00D

A framework for redistributing manure to meet regional production, economic, and environmental goals. Managing manure is one of the most difficult challenges of modern agriculture because excess manure can negatively affect water quality for human and environmental health. ARS scientists in Las Cruces, NM, and Tifton, GA, led a collaboration across 10 sites in the ARS Long-Term Agroecosystem Research (LTAR) network to classify 3,109 counties as "sources" of manure nitrogen and phosphorus from confined livestock production, or "sinks" that can use these nutrients to improve crop or hay production. The resulting four "manure sheds" represent various regional combinations of beef, dairy, poultry, and swine industries, and differ in the transport distances needed to productively use manure, from an average of 90 miles for a cattle-dominated system to 200 miles for a poultry-dominated system. Diverse stakeholders, including crop and livestock farmers, university extension staff, developers of manure-treatment technologies, and policymakers, can use the manure shed concept to develop strategies for recycling manure and transforming it from a liability to a valuable resource. (NP216, C1, PS1C, PS1D, C3, PS3A, Project No. 3050-11210-009-00D and Project No. 6048-11130-005-00D

An inexpensive portable high throughput phenotyping (HTP) system for rapid crop assessment and precision management. Phenotyping is the process of collecting data about an organism's physical characteristics, which is useful for research in breeding better crop species or assessing plant response to stresses like drought and heat. Manually collecting this data is very time-consuming and requires a lot of labor, so scientists are working on ways to increase throughput by automating these measurements. An ARS researcher from Maricopa, AZ, developed and tested a low-cost wireless HTP system powered by a solar rechargeable battery. This system measures vegetation index, canopy temperature, and height from a multispectral camera, an infrared (IR) thermometer, and mini-LiDAR sensors, respectively. This portable system can be mounted to unmanned aerial or terrestrial vehicles (drones) for use in fields or to indoor platforms for use in greenhouses or vertical farms. Because it is wireless, the data can be easily monitored from a smartphone or computer. The HTP system enabled automated irrigation control in a plant growth chamber based on soil water condition and automated collection of phenotypic data for months. This innovative data collection system has the potential to be adapted for use in commercial precision agriculture. (NP216, C1, PS1A, Project No. 2020-11000-013-00D)

Perennial crops improve crop, livestock, and timber production. ARS researchers in Mandan, ND, teamed up with scientists in 9 countries to show that: (1) a change from annual to perennial crops over 20 years led to an average 20-percent increase in carbon in the top 12 inches of soil and a 10-percent increase in the top 40 inches; and (2) woody crops were most effective at increasing soil carbon. ARS researchers in Ames, IA, along with university collaborators, showed that widely-spaced oak and pecan trees near Fayetteville, AR, removed and stored in their above-ground biomass 0.75 and 0.2 Mg carbon per hectare per year, respectively, while enabling simultaneous livestock and timber production. This

information is useful to producers who wish to combine agricultural production with environmental benefits of carbon removal from the atmosphere, and to people who are developing carbon offset markets that enable farmers to receive additional payments for this environmental service. (NP216, C1, PS1C, C3, PS3B, Project No. 3064-21660-004-00D and 5030-11610-005-00D)

Making Southwestern agricultural systems more resilient to weather variations. Weather-related challenges in southwestern U.S. communities and ecosystems include crop loss, extreme drought, variability in rangeland production, and wildfire. As members of the USDA Southwest Climate Hub (SW Climate Hub), ARS scientists in Las Cruces, NM, developed an online dust mitigation handbook with the Natural Resources Conservation Service (NRCS) and contributed to the AfterFire toolkit, an online post-fire resource for water managers. They also hosted an urban tree adaption workshop, expanded Grass-Cast (a forage production forecasting tool) to New Mexico and Arizona, conducted a survey of cattle producers to understand vulnerabilities to climate change and adaptation options, and co-launched the Drought Learning Network with climate scientists and land managers. These activities will assist farmers, ranchers, foresters, and other land managers in developing and implementing strategies to adapt to the impacts of extreme weather. (NP216, C2, PS2C, Project No. 3050-11210-009-00D)

Pelletizing makes manure easier to transport from livestock facilities to fields. ARS researchers in Mississippi State, MS, evaluated the effects of using pelleted manure as a source of fertilizer nutrients and organic matter in corn, soybean, and cotton fields over 4 years. Grain and lint yields were comparable between pelleted manure and inorganic fertilizer nitrogen at equivalent nitrogen rates, while

pelleted manure reduced nitrate percolation below the root zone. The practice of applying pelleted manure reduces the need for inorganic fertilizers and enables growers to maximize the return on their nutrient management practices while minimizing adverse impact on water quality. (NP216, C1, PS1C, C3, PS3B, Project No. 6064-21660-001-00D)

Mapping wheat grain protein concentration on-combine. Protein concentrations affect wheat quality and price, but the ability to map concentrations during harvest is unrealistic based on the high cost (more than $20,000) of commercially available spectrometers. ARS scientists in Pendleton, OR, adapted a moderately-priced reflectance spectrometer (less than $5,500) for use on a combine to measure and map the protein concentration of wheat during harvest. When calibrated, this instrument produced a protein map that was comparable to a map derived from a more expensive instrument. Having a less costly instrument for mapping protein across fields will enable more farmers to implement precision nitrogen management and to segregate and blend grain to achieve the desired quality. (NP216 C2, PS2B, Project No. 2074-12210-001-00D)

Biosensor enables farmers to more confidently use seed meal as a soil amendment. Seed meal produced from canola and mustard can reduce pathogen pressure and suppress the germination of weeds by releasing glucosinolates (GCSs) and isothiocyantes (ITCs) into the soil. However, the widespread use of canola and mustard-based seed meal is hampered because these compounds can also suppress the germination of crop plants. Scientists in Corvallis, OR, developed a bacterial biosensor that detects biologically relevant concentrations of GCSs and ITCs in soil at much lower cost compared with advanced instrument methods. This technology is being developed into a method that can rapidly screen

soils for the presence of ITCs, allowing growers to determine when it is safe to replant fields after the application of seed meals without suppressing crop germination. (NP216, C2, PS2B, Project No. 2072-12620-001-00D)

Managing brush encroachment in desert grasslands. Arid grassland is degraded when woody plants crowd out grasses, resulting in intensified erosion. ARS scientists in Las Cruces, NM, established a collaborative long-term distributed experiment to measure the conservation effects of brush management in 45 treatment areas across southern New Mexico. Analysis of data from 5 to 10 years of vegetation monitoring indicates that grass restoration is favored at higher elevations and on specific ecological sites, whereas shrub reinvasion after treatment is more likely in soils with higher clay content and when shrub cover was initially high. This study will help land managers improve the success rate of grassland restoration efforts by predicting the effects of brush management on conservation and forage production outcomes. (NP216, C1, PS1B, Project No. 3050-11210-009-00D)

Winter flooding of rice fields improves soil biology and waterfowl habitat but increases carbon footprint. ARS researchers in Jonesboro, AR, and Mississippi State, MS, evaluated trade-offs associated with a flooded winter fallow management option that is recommended by some conservation planners to provide waterfowl habitat. Winter flooding is beneficial for soil health as measured by soil biological activity, microbial groups, and plant nutrients, apparently due to fecal deposition by waterfowl as they frequent the flooded fields. However, methane gas emissions are higher during flooded than non-flooded fallow and can equal as much as 20 to 30 percent of those produced during the rice growing season. ARS researchers also found that methane can be reduced by up to half during the

growing season, relative to conventional practices, when rice farmers use intermittent flooding, a water-conserving irrigation practice. These results show that methane emissions created by winter flooding can be offset by careful irrigation management during the rice growing season while protecting grain yield and groundwater resources. This information provides guidance to rice farmers who wish to manage their cropping system for profitability and environmental sustainability. (NP211, C, PS1C, NP216, C1, PS1A, C3, PS3B, Project No. 6064-21660-001-00D and Project No. 6024-13000-003-00D)

Cover crops and compost increase soil health in long-term vegetable rotations. Soil organic matter often declines in tillage-intensive vegetable production systems, which can reduce soil health and productivity. Farmers working to improve soil management strategies need long-term information on how organic matter inputs from compost and cover crops affect soil organic matter levels. ARS researchers in Salinas, CA, and Beltsville, MD, evaluated changes over 8 years in soil organic matter in several vegetable rotations in the Salinas Valley that differed in the amount of organic matter input from winter cover crops and yard-waste compost. Although compost and cover crops both increased soil organic matter levels, frequent cover cropping had a greater impact on the type of organic matter that is more closely linked to increased crop yields and nutrient cycling. This information is useful to vegetable producers who seek to improve the profitability of their cropping systems through improved soil health. (NP216, C2, PS2A, PS2B, Project No. 2038-21620-014-00D and Project No. 8042-21660-005-00D

High-quality forage can be produced from cover crops in place of summer fallow. Summer fallow degrades soil quality and is a non-sustainable cropping practice. Planting cover crops in place of fallow helps improve soil quality and can also provide a source of high-quality forage. ARS researchers in

Sidney, MT, planted a 10-species crop mix (buckwheat, cowpea, flax, lentil, millet, mustard, pea, radish, sorghum, and turnip) in place of fallow in 2-year durum wheat rotations from 2014 to 2019. When harvested in early summer, this mixture produced prime quality forage at an average of 1.5 tons per acre. After forage harvest, regrowth of cover crops terminated by killing frost averaged 2.9 tons per acre of unharvested standing cover. Given the growing interest among producers in incorporating a diverse cover crop mix into their dryland cropping system to improve soil biological function, these results provide information about how a cover crop might also provide an immediate economic return when used as a forage. (NP216, C1, PS1A, C2, PS2A, C3, PS3B, Project No. 3032-13210-007-00D)

Reducing our carbon footprint with renewable fuels grown on marginal land. ARS researchers in University Park, PA, showed that ethanol could be produced from barley with a carbon footprint less than half that of gasoline, allowing it to meet the advanced fuel standard of the U.S. Environmental Protection Agency. ARS scientists in Mandan, ND, along with scientists at Michigan Tech and the U.S. Department of Transportation, demonstrated that growing oilseeds in place of fallow in non-irrigated areas of the Great Plains reduces greenhouse gas (GHG) emissions, increases soil carbon, and could boost regional farmer incomes from $127 million to $152 million per year through jet fuel production. ARS scientists in Lincoln, NE, and Fort Collins, CO, determined that, compared to GHG-neutral continuous corn under conservation management, long-term (16 years) switchgrass systems mitigate GHG emissions during feedstock production by capturing more carbon in soil and mitigating nitrous oxide loss. ARS researchers in Temple, TX, identified genetic information in switchgrass that enables it to adapt to different growing conditions across a regional gradient from Texas to South Dakota. This research provides farmers with information about how to diversify income through emerging renewable

fuel markets and provides policy makers with data needed to create programs to support renewable fuel production. (NP216, C1, PS1A, C3, PS3C, Project No.8070-66000-001-00D, Project No. 3064-21660-004-00D, Project No. 3042-11210-003-00D, Project No. 3098-11000-001-00D, Project No. 3012-11120-001-00D)

Improved methods to provide fertilizer recommendations and predict the effects of soil conservation practices on soil erosion. ARS scientists in Columbia, MO, along with scientists at 8 Midwest universities, evaluated 31 publicly available tools used in 49 field experiments to determine nitrogen fertilizer recommendations for corn. They found that yield-goal-based tools recommended more nitrogen than necessary and that the tools using soil nitrate tests or measurements of leaf color came closest to the economically optimal nitrogen rate. ARS researchers in Tifton, GA, demonstrated the importance of using variable-rate simulated rainfall tests, rather than the more common constant-rate simulation to measure soil erosion and nutrient loss under different tillage practices. Typical rainfall events were reflected more accurately when rainfall rate was varied during the simulation, while the advantage of no-till practice compared with conventional tillage was found to be diminished during high-intensity rainfall. This analysis of scientific methods is useful to scientists who want to improve the accuracy of their models as well as to land managers who want to improve their nitrogen management and soil conservation practices. NP216, C1, PS1A, C2, PS2C, C3, PS3A, Project No. 5070-12610-005-00D and Project No. 6048-11130-005-00D

Evidence grows that reducing tillage intensity and planting cover crops improves soil health. Improving soil health builds the capacity of the soil to function as a vital, living ecosystem that sustains

plants and animals, but it is a challenge to adequately measure the improvement that management practices have on soil health. ARS scientists in Ames, IA, and Columbia, MO, conducted a meta-analysis of 302 published studies throughout the United States to assess the effects of chisel plowing (CP), no-tillage (NT), and perennial cropping systems (PER) relative to moldboard plow (MP) on seven soil health indicators: soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, soil respiration, active carbon, beta-glucosidase activity, and soil protein within 4 soil depth increments. Overall, reducing tillage by converting from MP to CP improved topsoil organic carbon, microbial biomass carbon, and respiration, whereas converting from MP to NT significantly increased all seven soil health indicators in the topsoil. Below the topsoil, NT resulted in greater microbial biomass, microbial carbon, respiration and beta-glucosidase activity relative to MP. Based on this analysis, reducing tillage intensity, planting cover crops, and/or minimizing crop residue removal within annual cropping systems can significantly improve soil biological health in the United States. Soil biological indicators are sensitive to management practices, confirming their utility in soil health assessment. Scientists can use this analysis to choose soil health measurements in their experiments that test the sustainability of different agricultural practices, and farmers will have added confidence that recommended practices improve soil health in a measurable way. (NP216, C1, PS1A, Project No. 5030-12210-003-00D)

Powerful tools and techniques for monitoring rangeland production systems improve management and lower production costs. Standardized approaches for monitoring rangelands are needed to allow land managers and public land agencies to collect and share data that address numerous rangeland management and policy needs. ARS scientists in Las Cruces, NM, led the expansion of the rangeland

monitoring program that directly supports the Bureau of Land Management (BLM) and USDA, Natural Resources Conservation Service (NRCS) national inventory and monitoring programs and the interagency National Wind Erosion Research Network. The Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems was published online, and physical copies were distributed to field staff. Statistical analysis tools and datasets were used by BLM and NRCS to produce reports and make management decisions regarding wildlife habitat suitability, evaluate conservation practice effectiveness, and improve grazing management systems across the continent's rangelands. (NP216, C1, PS1A, PS1B, Project No. 3050-11210-009-00D)

Removal of corn residue in semiarid irrigated systems reduces water use efficiency. Removing residue from corn fields for biofuel production offers an opportunity to increase farmer profits, but there are potential tradeoffs for water availability and crop performance. A multi-year collaboration between ARS researchers in Akron, CO, and scientists from Colorado State University compared the effects of two tillage practices (no-till and conventional), and two corn residue management practices (harvested and retention) on grain yields, water infiltration, evaporation, and soil quality. Corn grain yields increased and evaporative water losses were reduced with residue retention, especially under no-till. Water infiltration into the soil was higher with residue retention, resulting in higher water content in the soil at planting. The study suggests that high rates of crop residue removal under limited irrigation can negatively affect water conservation and yields, and that tradeoffs surrounding residue export need to be considered. These results will help irrigated corn growers in the region make better residue management decisions. (NP216, C1, PS1A, Project No. 3010-12210-004-00D)

CROP PRODUCTION AND PROTECTION

National Programs:

- **Plant Genetic Resources, Genomics and Genetic Improvement, NP 301**
- **Plant Diseases, NP 303**
- **Crop Protection and Quarantine, NP 304**
- **Crop Production, NP 305**

Redesigning soybean meal for nonruminant animals. Soybean is the top global source of protein meal for animal feed. Soybean seeds, however, contain carbohydrate compounds called raffinose family oligosaccharides (RFOs) that prevent effective digestion of soybean meal in nonruminant animals. To combat this problem, ARS scientists in West Lafayette, IN, and Columbia, MO, collaborated with university partners to identify and incorporate new genes to reduce or eliminate RFOs in soybean meal. A soybean population treated with an agent to induce mutations was screened to generate desirable genes in the RFO biosynthesis pathway. A new mutant was recovered from this screen that reduced RFOs from 5 to 6 percent of total carbohydrates to below detectable levels when used in combination with other modified RFO soybean genes. Essentially, a “No-RFO” soybean was created. Field studies established the stability of the genes, and feeding trials demonstrated that “ No-RFO” soybean meal

improved poultry growth and nutrition. The researchers discovered close associations of the genes controlling the modified RFO plant type with molecular markers that can be used to detect the variant alleles during breeding. These discoveries have been shared with public soybean breeders, as have the modified seeds and marker information that can be used to enable marker-assisted selection for improved soybean meal that can add value to soybean by improving the metabolizable energy of the meal. (NP301, C1, PS1B, Project No. 5020-21000-008-00D and 5070-21000-040-00D)

A covert killer of macadamia trees discovered in Hawaii. Currently more than 17,000 acres (approximately 1.2 million trees) of macadamia nut are grown in Hawaii, constituting a $42 million/year industry. Early detection and identification of newly emerging diseases are the critical first steps for protecting this valuable crop. ARS researchers in Hilo, HI, published the first report of *Phytophthora heveae*, a plant pathogen, as the cause of macadamia quick decline and the first report of this pathogen on any host plant in Hawaii. *Phytophthora heveae* has a wide host range, and its presence in Hawaii also poses a potential risk for avocado, mango, and cacao. ARS researchers are working with macadamia growers and researchers to assess the impact of Phytophthora diseases and develop improved management practices that minimize tree loss in mature orchards and maintain the economic viability of the macadamia industry. Commercial macadamia production originated in Hawaii, which now produces nuts that are considered the global “gold standard” for quality and flavor. (NP301, AP 2018-2022, C2, PS2a, Project No. 2040-21000-016-00D)

Characterization of the changes responsible for increased stalk pathogen- and drought-resistance in brown midrib 12 (bmr12) sorghum. ARS researchers in Lincoln, NE, examined how two brown

midrib lines (bmr6 and bmr12) and the corresponding normal sorghum line responded to two stalk diseases (Fusarium stalk rot and charcoal rot) under drought stress and adequate water conditions. Bmr12 plants have impaired lignin synthesis; lignin is a cell wall component that plays a role in plant defenses against drought and pathogen attack. Bmr12 plants had fewer disease symptoms under drought conditions than normal plants or even bmr12 plants under adequate water conditions. Further analyses show that bmr12 had increased defense signals under drought conditions, which suggested these plants were already prepared for a pathogen attack. This research showed that bmr12 sorghum with reduced lignin may have improved ability to serve as a forage and bioenergy crop. The identification of genes and pathways in bmr12 plants that direct lignin synthesis may lead to the development of more climate- and disease-resilient sorghum hybrids. (NP301, C3, PS3A; NP303, C3, PS3A, Project No. 3042-21220-033-00D)

Identification of romaine lettuces with reduced browning discoloration for fresh-cut processing. Lettuce is one of the most valuable fresh vegetables and one of the top 10 most valuable crops in the United States, with an annual farm-gate value of more than $2.5 billion. Fresh-cut lettuce is the primary ingredient of the increasingly popular packaged, ready-to-eat salads; however, discoloration (browning) represents a major challenge that limits its quality and shelf life. Processors who lack effective browning control methods are relying on modified atmosphere packaging (MAP) to achieve low oxygen atmospheric conditions and maintain the shelf life. ARS researchers in Salinas, CA, and Beltsville, MD, identified lettuces with limited browning that will be used in breeding programs and to help identify genes associated with limited browning. These findings are of great benefit to the U.S vegetable industry. (NP301, C1, PS1A, PS1B, Project No. 2038-21530-002-00D)

Under-the-radar dengue virus infections in natural populations of *Aedes aegypti* mosquitoes. Metagenomics has helped identify dengue virus in Florida prior to any human infection. ARS researchers in Stoneville, MS, have demonstrated the ability to monitor vector-borne diseases ahead of outbreaks using metagenomics. To date, the current U.S. public health system's response to outbreaks has been largely reactive, but this research shows that by monitoring mosquito populations, it may be possible to identify emerging mosquito-borne diseases in high-risk, high-tourism areas of the United States to enable proactive, targeted vector control before potential outbreaks occur. (NP301, C3, PS3A, Project No. 6066-21310-005-00D)

New hybrid hemlock 'Traveler' is resistant to insect pests. The native hemlock, *Tsuga canadensis*, plays an essential role in forest ecosystems and cultivated landscapes; however, it is susceptible to feeding damage by the hemlock woolly adelgid, which has caused widespread loss of hemlocks in wild and cultivated settings. ARS scientists at the U.S. National Arboretum in Washington, D.C., developed and introduced the first interspecific hybrid hemlock to the trade. 'Traveler' is a cross between the Chinese hemlock and the Carolina hemlock. It was explicitly bred for resistance to hemlock woolly adelgid and selected for its regular and slightly pendulous shape and its moderately slow growth rate. It is currently being propagated under license at cooperator nurseries and promises to be a valuable addition to residential, commercial, and forest landscapes. (NP301, C1, PS1B, Project No. 8020-21000-071-00D)

Genetic mapping of traits associated with pollinator visitation, yield, and seed size in sunflowers. Pollination by wild bees increases yields of both oilseed and confection sunflowers, and bees prefer

sunflowers with shorter florets for easier nectar access. In addition, seed size (length and width) is important in the confection sunflower market. ARS scientists in Fargo, ND, and University of Colorado-Boulder colleagues mapped genes associated with both floret depth and seed size to specific chromosomal locations in cultivated sunflowers and designed genetic markers to use in identifying desirable lines carrying both those traits. Floret length and seed length are correlated, but when the team mapped these traits, they discovered that the genetic bases for the two traits are largely independent and can be improved separately. Markers developed for seed and floret length will improve private- and public-sector breeding by allowing effective selection of lines that are attractive to bees and possess desirable seed size and shape for the confection sunflower market. These cultivars will provide ecosystem services for bees and economic value for sunflower producers and consumers. (NP301, C1, PS1B, Project No. 3060-21000-043-00D)

Understanding the genome sequence of pecan. Understanding the detailed genetic makeup of pecan is critical to advancing breeding efforts. The whole genomes of the pecan cultivars 87MX3-2.11, ‘Lakota’, ‘Elliott’, and ‘Pawnee’ were sequenced by ARS researchers in College Station, TX. This also includes sequencing the pecan chloroplast, a small, extra-nuclear genome that is critical for photosynthesis and that is generally passed from the mother to the offspring. Because of this unique inheritance pattern, chloroplast genomes can be used to trace maternal origin over many generations. Sequence data provide the genetic blueprint of gene location and function, thus establishing foundational information to support pecan genetic research for years to come. This accomplishment is critical for future work to establish the origin of pecan in North America, to define evolution of the species, and to guide ongoing efforts to improve pecan trees through breeding. (NP301, C4, PS4A, Project No. 3091-21000-039-00D)

Evaluation of blueberry genetic resources identifies fruit fly resistance. Spotted wing drosophila fruit fly appeared in the United States in 2009 and now causes more than $511 million in damage annually to fruit production in Western States. ARS scientists from Corvallis, OR, and Poplarville, MS, searched blueberry genetic resources for resistance to that fruit fly. Twenty-nine blueberry species were tested with a bioassay for resistance to feeding by the fruit fly larvae and adults. Ten blueberry species were resistant to feeding by the fruit fly; three of those species are indigenous to East Asia, in the fruit fly's native range. Blueberry species from Central and South America were also resistant. Most highbush blueberry cultivars were susceptible, but rabbiteye and other blueberry cultivars with smaller, firmer fruit types were resistant. These findings will enable blueberry breeders to identify parental lines to cross and produce new blueberry cultivars resistant to this fruit fly. (NP301, C1, PS1a, Project No. 2072-21000-049-00D).

'Galena Russet' is a new potato variety with high yield and attractive tubers suitable for multiple uses. U.S. potato production is valued at $4 billion annually. However, the industry needs new potato varieties with high yields and better processing quality. ARS scientists in Aberdeen, ID, along with researchers at experiment stations in Idaho, Oregon, and Washington, released and filed for Plant Variety Protection for 'Galena Russet' is a new potato variety that produces high yields in both early and full-season harvests, allowing for use over more growing areas. 'Galena Russet' has excellent processing characteristics for fries due to cold sweetening resistance, allowing for lighter colored fries late in the storage season. This is an improvement over other varieties in which conversion of starch to sugar results in a darker product. 'Galena Russet' has an attractive tuber shape and low levels of defects,

making this a good fresh market potato. This new potato variety will greatly benefit the potato industry. (NP301, C1, PS1B, Project No. 2050-21000-035-00D)

Breeding Insight supports ARS specialty crop and animal breeders. ARS specialty crop breeders are often the sole source of publicly available new crop varieties for farmers and growers across the United States and elsewhere. Although specialty crops and animals are a large portion of gross U.S. agricultural revenue, individually these small programs have not had access to innovations that benefited major crop and animal breeding programs and thus have lagged. The ARS Breeding Insight Platform is currently in a pilot phase focused on building support services for six ARS breeding programs (blueberry, table grape, sweet potato, alfalfa, rainbow trout, and North American Atlantic salmon), with the future goal of expansion to all ARS specialty crops, animal, and natural resource breeding programs. The project identified the key workflows common to these diverse programs and initiated the development of extensive software and genomics to support these efforts. Genomic support was delivered for all programs. A key early success was integrating the leading field data collection tool with the community's leading database. Providing powerful information and genomic tools to ARS specialty crop and animal breeders is helping to improve breeding decisions, meet public demands for more nutritious and flavorful foods, and improve food security for the United States and its trade partners. (NP301, C2, PS2A, Project No. 8062-21000-043-00D)

New food barley variety with a winter growth habit provides additional options for growers. Winter cereal varieties can provide growers with options to manage soil moisture resources and to minimize crop losses to biotic and abiotic stress pressures. The A new winter barley cultivar,

'Upspring', is the first two-row food barley cultivar that will fill this niche. Upspring is the product of breeding by ARS researchers in Aberdeen, ID. The new cultivar is well balanced in yield, winter hardiness, and quality traits with high beta-glucan content. (NP301, C1, PS1B, Project No. 2050-21000-034-00D)

Stopping blue mold fungus decay in apples. Apples are one of the most popular fruits consumed in the United States, and may be stored for up to 12 months. During storage, the blue mold fungus may cause the apple to rot, reducing its quality and marketability. ARS researchers in Beltsville, MD, in collaboration with University of Wisconsin, Pennsylvania State University, and Dartmouth University colleagues, have discovered a way to block the gene in the blue mold fungus that causes apple rot in storage. The apple industry and researchers are using this new knowledge to develop postharvest decay treatments for the blue mold fungus. (NP303, C1, PS1A, Project No. 8042-42430-002-00D)

Combining herbicides with biofumigants for better pest and disease control. The loss of methyl bromide has left growers with few soil fumigant options, particularly for buffer zone areas where conventional fumigants cannot be applied. Alternatives to methyl bromide are urgently needed for both conventional and organic crop production. ARS researchers in Fort Pierce, FL, conducted field trials on tomato and bell pepper plants in Florida using a combination of herbicides and a newly registered pre-plant biofumigant with the active ingredient allyl isothiocyanate. The treatments resulted in broad-spectrum control of pathogens and weeds to a degree that was equivalent to when methyl bromide was used, including lower incidence of bacterial wilt of tomato, lower populations of root-knot nematodes in soil, and fewer nutsedge weeds. Herbicide and biofumigant combinations provide a greatly needed

option for controlling crop pests and diseases in both conventional and organic crop production in Florida and elsewhere. (NP303, C3, PS3C, Project No. 6034-22000-043-00D)

Precision thermotherapy lowers leaf spot on strawberry. In small-scale experiments, heat treatment has previously been shown to be an effective way of managing the bacterium that causes angular leaf spot (ALS) on nursery stocks of strawberry. ARS researchers in Fort Pierce, FL, designed, built, and tested a commercial-scale precision thermotherapy unit for applying a new thermotherapeutic protocol that combined two heat treatments, a conditioning thermal treatment and an eradicative thermal treatment. Several trials were conducted in cooperation with commercial nurseries to determine the effects of thermotherapy on plant health and on the natural development of ALS. Overall, precision thermotherapy had a negligible effect on plant growth and yield. When ALS occurred, its effect was always lower in plots that received the thermotherapy treatment. Successfully scaling up thermal treatment of nursery stock to commercial levels could help control pests and diseases while simultaneously reducing or eliminating pesticide use against a broad range of threats to sustainable strawberry production. (NP303, C3, PS3A, Project No. 6034-22000-042-00D)

Integration of linkage blocks of wheat stem rust (Ug99) resistance genes. The finding that genes that support disease resistance in wheat are linked is a great asset for gene stewardship that will serve to extend the life of resistance in modern varieties. ARS researchers in St. Paul, MN, have effectively combined multiple linked genes that are effective against Ug99 and backcrossed these linkage blocks into conventional wheat germplasm. Two resistance genes were combined on one chromosome arm, and two other genes were combined on a different chromosome arm. The two linkage blocks were

backcrossed into hard red spring wheat cultivars that previously had been released by the University of Minnesota and South Dakota State University. The Ug99-resistance-enhanced lines have been used to develop new wheat cultivars with multiple Ug99-resistant genes. (NP303, C3, PS3A, PS3B, Project No. 5062-21220-023-00D)

Creation of a genomic database for a major soilborne pathogen. *Rhizoctonia solani* is a soilborne plant pathogen with a wide host range and worldwide distribution. It is difficult to precisely identify the various isolates of the pathogen complex because the pathogen produces no spores. Genomes of 13 isolates from the *R. solani* plant pathogen complex were sequenced, assembled, and annotated, and a genome database was created that is publicly accessible. This database provides scientists with information that is critical for the development of methods for identifying various isolates within the *R. solani* pathogen complex. Identification and differentiation of the many morphologically similar *R. solani* species is necessary to develop appropriate plant disease control measures. (NP303, C3, PS3B, Project No. 8042-21220-181-00D)

DNA sequence resources for bacterial plant pathogens of economic importance. The separate pathogens that cause almond leaf scorch, olive quick decline, and citrus greening have significant impacts on crop production worldwide. DNA sequences from these pathogens can be used for detection, surveillance, and disease tracking purposes. ARS scientists in Parlier, CA, and Byron, GA, with collaborators in Brazil used next-generation sequencing technology to create whole-genome sequencing data generated through multiple short- and long-sequences for pathogen strains associated with olive in California and pecan in Georgia. The scientists were also able to fully sequence a citrus greening

pathogen strain from Brazil. This new DNA sequence information is valuable for development of new disease management and diagnostic strategies, and for pathogen detection and quarantine applications. (NP303, C2, PS2A, Project No. 2034-22000-012-00D)

Epidemiological models predict the spread of two severe citrus diseases by hurricanes. Asiatic citrus canker (ACC) and citrus black spot (CBS) cause economic damage and are severe impediments to international trade of citrus as a commodity. ACC, caused by a bacterium, and CBS, caused by a fungus, are both dispersed by rain splash. During a hurricane, such rain splash can be spread over many miles. Two such hurricanes, Harvey in southeast Texas and Irma in southwest Florida, potentially spread ACC and CBS, respectively, in 2017. ARS researchers in Fort Pierce, FL, adapted and extended a previously developed hurricane dispersal model to address both diseases and make predictions for where these infections may have spread due to the hurricanes. The results of these model predictions were presented to regulatory agencies and science advisory committees in Florida and Texas. ARS researchers also developed a model to predict where to look for pathogen entries that were rejected by the hurricane models. As a result, regulatory agencies in both States in collaboration with the USDA, Animal and Plant Health Inspection Service have deployed the surveys for early detection of potential spread of these diseases in both States. (2017, NP303, C2, PS2B, Project No. 6034-22000-042-00D)

First report of grapevine red blotch virus in Idaho. Some grapevine viruses are detrimental to grapevine health, crop load ratio, fruit characteristics, and ultimately to wine quality, while others cause only minor issues. ARS scientists in Parma, ID, and University of Idaho collaborators conducted research on grapevine viruses in collaboration with commercial grape growers. This work is the first

report on the presence of grapevine red blotch virus (GRBV) in Idaho commercial vineyards. Multiple years of sampling and testing for GRBV indicate the spread of this virus is limited in Idaho. These findings can be used by the grape industry for making vineyard replanting decisions. (NP305, C1, PS1B, Project No. 2072-21000-052-00D)

Plant "organ transplants" offer a new way of delivering genetic engineering solutions to solve crop pest/pathogen problems. There is an urgent need for solutions to control whitefly and the diseases transmitted by it. ARS researchers in Fort Pierce, FL, in collaboration with a private-industry partner, developed a method of engineering only a group of plant cells that can be attached to other plants (essentially as a new organ) to produce desired molecules that are secreted into the plant vascular tissue and move throughout the plant. This "new organ" cannot survive away from the plant and does not move from the location where it is attached, thus the harvested commodity (i.e., fruit, nut, etc.) is not genetically engineered. It also cannot form whole plants, seed, or pollen, thus there is no escape of genetic material. The scientists are evaluating the ability of this strategy to cure trees infected with *Huanglongbing* (HLB, aka citrus greening) by engineering similar organs to produce natural peptides and double-stranded RNA that kills the HLB-causing bacterium, and attaching these organs to ornamental and/or horticultural crops. Proof-of-concept has been completed in tomato. This strategy could be adapted as a means to rapidly deliver genetic engineering solutions in an environmentally sustainable and consumer acceptable method. (NP304, C3, PS3c, Project No. 6034-22320-003-00D)

Establishment of a new biological control agent of Cape-ivy. Cape-ivy (*Delairea odorata* Lem.) is a vine-like perennial weed that has invaded sensitive coastal streambank, forest, and scrub habitats along

the California coast, and it is also invasive in Hawaii, Australia, and southern Europe. Cape-ivy smothers native herbs, shrubs, and trees and can clog coastal streams that supply agricultural water. ARS scientists in Albany, CA, released a fly from Cape-ivy's native range in South Africa that makes tumor-like galls in Cape-ivy's shoot tips, which reduces shoot tip abundance and growth. The fly is the world's first biological control agent against Cape-ivy. Releases were conducted at 18 field sites in California between late 2016 and 2019. The fly has established large populations at four sites, including two California State parks, with gall abundance increasing 40-fold since early 2019. Continued dispersal and galling will decrease Cape-ivy's competitive advantage and invasiveness. (NP304, C2, PS2b, Project No. 2030-22000-027-00D)

Beneficial nematodes complete their first trip to space. In an exciting collaboration between ARS researchers in Byron, GA, and industry partners, beneficial insect-killing nematodes (small roundworms) were sent to the International Space Station in support of the goal of developing environmentally friendly methods to support long-term space travel. Beneficial nematodes, also called entomopathogenic nematodes, are alternatives to using broad-spectrum chemical insecticides and are also safe to humans and other nontarget organisms. They are used to control a wide variety of insect pests on Earth. The nematodes sent into space were capable of navigating through soil and killing insect pests. This was the first biological control experiment in space. The mission represents a look into the future where food crops will be grown in space. (NP304, C3, PS 3a, Project No. 6042-22000-023-00D)

Frequency of pathogen transmission by stink bugs elucidated. It has been well established that stink bugs can transmit damaging plant pathogens that cause significant decline in cotton seed and lint yield.

But the ability of individual stink bugs to infect multiple cotton bolls in succession, and the frequency of this occurrence, had not been known. ARS researchers in College Station, TX, discovered that an individual southern green stink bug can infect as many as five cotton bolls in succession. This discovery provides a basis for revising stink bug treatment thresholds, which are currently based simply on numbers of stink bugs per unit area but do not consider whether the bugs may be carrying and depositing pathogens.

New methods to control invasive horticultural pests and pests of quarantine importance. Alternatives to methyl bromide fumigation are urgently needed for treating economically important insect pests of harvested fruit. ARS scientists in Parlier, CA, developed a novel postharvest fumigation protocol to control codling moth that were infesting shelled walnuts packed in new fiberboard cartons. U.S. exports of shelled walnuts to Japan are valued at $80 million annually. A quarantine protocol for trailers containing citrus using postharvest fogging was developed against Asian citrus psyllids. A fumigation protocol using phosphine was developed against bean thrips to retain U.S. market access for fresh citrus to New Zealand, valued at $20 million annually. Phosphine fumigation protocols were also developed to control black widow spiders and spotted wing drosophila to retain U.S. market access for table grapes to Australia valued at $180 million annually. This ARS research directly resulted in market retention or expansion and served as the basis for interaction between industry, USDA, Foreign Agricultural Service, USDA, Animal and Plant Health Inspection Service, and respective counterparts in other countries. (NP304, C4, PS4a, Project No. 2034-43000-040-00D)

Integrated West Nile virus (WNV) early warning surveillance system developed. West Nile fever/encephalitis is the most important mosquito-borne disease in the continental United States. The disease is caused by a flavivirus that is separated into distinct lineages, with lineage 1 (L1) and lineage 2 (L2) encompassing all WNV known isolates associated with human and veterinary disease. Currently, all known U.S. WNV isolates belong to L1. L2 isolates, usually found in sub-Saharan Africa, were recently found in Europe and caused large human and equine WNV outbreaks. The invasive threat and risk of WNV L2 invading the United States is significant because recent evidence has demonstrated that North American mosquito species are competent vectors of WNV L2 isolates from Africa and Europe. ARS scientists in Greece associated with the European Biological Control Laboratory designed an integrated WNV early warning surveillance system specifically targeting the L2 strains. The system relies on detecting viral RNA in field-collected mosquitoes and screening sentinel chickens for WNV-specific antibodies. The surveillance system was successfully implemented and provided information on WNV mosquito circulation and enzootic transmission 1 month prior to human cases, thereby allowing for targeted and proactive vector control interventions. Knowledge of the WNV L2 ecology in Europe combined with optimized field-based surveillance systems and laboratory diagnostic tools can be applied to enhance early detection and early warning systems to control and reduce this emerging threat. (NP304, C3, PS3a and PS3b, Project No. 0212-22000-027-00D)

Genes identified in insects that infest stored food products. Understanding the factors that allow insects to colonize different types of stored products will ultimately lead to tactics that can reduce and prevent infestations. Using recently compiled insect genomes from Ag100Pest, the effort to sequence the top 100 agricultural pests in the United States, ARS scientists in Manhattan, KS, in conjunction with

researchers from University of Memphis, Indiana University, and several other research institutions have discovered rapidly evolving gene families that allow insects to adapt to new food sources. These gene families include those involved in the ability to perceive and respond to volatiles from food resources as well as those involved in the ability to digest complex carbohydrates present in plant cell walls and starchy foods. The ability to make long-read sequencing libraries from small amounts of insect tissue has greatly expanded the number of insect genomes scientists now have available to them and will lead to further insights into genetic adaptations that have allowed diverse lineages of insects to exploit stored commodities. (NP304, C4, PS4b, Project No. 3020-43000-032-00D)

Microalga as a promising nutritional supplement for honey bees. Feeding honey bees an artificial pollen substitute diet to support colony health during periods of reduced forage is a common management practice by beekeepers, but most substitute diets need improvement. Artificial diets may be deficient in essential macronutrients (proteins, lipids, prebiotic fibers), micronutrients (vitamins, minerals), and antioxidants. In an effort to improve artificial diets, ARS researchers in Baton Rouge, LA, evaluated the nutritional aspects of the microalga *Arthrospira platensis* (commonly called spirulina), finding that spirulina is rich in the essential amino acids and functional lipids commonly found in pollen. Nutritional physiology and microbiome evaluations of bees fed spirulina closely matched those of bees fed a natural pollen diet. The study results thus show that the alga has significant potential to serve as a pollen substitute or prebiotic diet additive to improve honey bee health. Results of the study were highlighted in the August 2020 edition of American Bee Journal. More broadly, adapting beekeeping and broader livestock management practices with microalgae feeds could contribute to achieving objectives outlined in the United Nations sustainable development goals related to food

security, sustainable water management, reversal of land degradation, and halting biodiversity loss. The long-term aim of this research is to characterize and develop microalgae as a sustainable feed source for honey bees that can be augmented via biotechnology to improve bee nutrition and health. (NP305, C2, PS 2A, Project No. 6050-21000-015-00D)

Universal intelligent spray control system as a retrofit for conventional sprayers commercialized. An intelligent spray technology developed by ARS researchers in Wooster, OH, effectively controls pest insects and diseases with significant reductions in pesticide waste to the environment; however, to ensure that growers use this technology economically, it must be adaptable to conventional sprayers. To address this challenge, the researchers developed a universal intelligent spray system as a retrofit unit for conventional orchard sprayers. The retrofit unit was tested in 15 commercial nurseries, fruit and nut orchards, and vineyards in California, Ohio, Oregon, South Carolina, Tennessee, Texas, and Australia. Field tests demonstrate this new technology can provide pest and disease control that is as effective as conventional spray systems while reducing spray drift by up to 87 percent and ground loss by 90 percent. In addition, pesticide use was reduced by up to 85 percent, resulting in an annual chemical cost saving of $812 per acre, depending on crop type. This cost reduction does not include reductions in labor and fuel costs. The technology was transferred to a commercial partner and a commercial product, “Intelligent Spray Control System” by Smart Guided Systems, LLC, was released to the market. Citrus, apple, grape, nursery, and pecan growers in the United States and other countries have started to upgrade their sprayers with the commercial product. The use of a new laser-guided intelligent spraying system is beneficial to the environment and saves growers money. The ability to retrofit conventional sprayers

offers a sustainable and environmentally responsible approach to protecting crops. (NP305, C1, PS 1E, Project No. 5082-21620-010-00D)

Bee genomics reveal a genetic basis of colony defensive behavior. Breeding using genomic tools has not yet been adopted by the honey bee industry. In part, this is because some of the traits of highest interest for bee breeding are regulated by many genes, which makes it a challenge to characterize them. In addition, honey bees live as a colony, and many relevant honey bee traits are measurable only at the group level. Colony defensive behavior is an ideal example in which many of these complications are evident. This trait is of particular interest to stakeholders because having bee colonies that are overly defensive is undesirable from both management and public health perspectives. By investigating the genomic structure of this clearly identifiable behavioral trait and using a novel population of gentle Africanized honey bees local to Puerto Rico, ARS researchers in Baton Rouge, LA, were able to identify a particular region in the genome that contributes to reduced colony defensive behavior. These findings provide a roadmap for the analysis of complex bee traits. (NP305, C2, PS 2A, Project No. 6050-21000-015-00D)

Pennycress as a cash cover crop promotes sweet corn sustainability. Commercial sweet corn production often results in substantial losses of nitrogen applied via fertilizer that end up in ground and surface waters as a pollutant. Growing a cover crop after sweet corn harvest to use excess leftover nitrogen could prevent this issue, but producers are reluctant to adopt this practice for economic reasons. ARS researchers in Morris, MN, in collaboration with University of Minnesota scientists, demonstrated that pennycress, which can double as an oilseed cover and cash crop, reduces the potential loss of

leftover nitrogen from sweet corn production by about 42 percent. Moreover, the excess nitrogen that pennycress scavenges is enough to produce adequate pennycress seed yields without adding any additional fertilizer. Results of these studies are relevant to farmers, extension specialists, and crop consultants searching for cover crop options that are both economically and environmentally sustainable. (NP305, C1, PS 1A, Project No. 5060-21220-007-00D)

The National Genetic Resources Program (NGRP). The NGRP is responsible for acquiring, characterizing, preserving, documenting, and distributing to scientists germplasm of all life forms important for food and agricultural production. In FY 2020, 203,922 samples were distributed to 279 foreign genebank/resources units; international agricultural research centers; U.S. and foreign commercial companies; and U.S. and foreign agencies and universities.

Site	Samples	Accessions	Requests	Countries
Cotton Collection (COT)	646	551	65	2
National Arid Land Plant Genetic Resources Unit (PARL)	146	125	22	3
National Laboratory for Genetic Resources Preservation (NSSL)	293	282	21	1
National Small Grains Collection (NSGC)	31,883	24,818	545	37
Natl. Germplasm Repository - Corvallis (COR)	5,693	2,726	889	10
Natl. Germplasm Repository - Davis (DAV)	5,708	3,140	236	8
Natl. Germplasm Repository - Geneva (GEN)	4,012	2,030	276	6
Natl. Germplasm Repository - Hilo (HILO)	168	109	42	5

Natl. Germplasm Repository - Mayaguez (MAY)	576	222	65	2
Natl. Germplasm Repository - Miami (MIA)	249	200	61	4
Natl. Germplasm Repository - Riverside (RIV)	230	213	11	4
North Central Regional PI Station (NC7)	45,539	20,029	1,119	49
Northeast Regional PI Station (NE9)	7,057	4,186	190	22
Ornamental Plant Germplasm Center (OPGC)	157	153	18	3
Plant Genetic Resources Conservation Unit, Griffin, GA (S9)	28,678	18,857	772	36
Plant Variety Protection Voucher Collection (PVPO)	45	45	3	1
Potato Germplasm Introduction Station (NR6)	3,530	1,429	174	11
Rice Genetic Stock Center (GSOR)	3,342	2,246	103	9
Soybean Collection (SOY)	18,987	11,671	346	17
U.S. National Arboretum (NA)	220	190	91	4
US Nicotiana Germplasm Collection (TOB)	326	252	68	8
Western Regional PI Station (W6)	46,437	30,266	893	37
Total	**203,922**	**123,740**	**6,010**	**279**

3.7. Outreach Activities: Workshops, Field Days, Trainings/Demonstrations, and Stakeholder Presentations/Meetings

AL	Soil Dynamics Research Unit	The laboratory was invited to present at the 2020 Tennessee Valley Cover Crop Field Day about cover crop mixtures and management. Participants were ag consultants and growers. There were approximately 75 attendees.
AL	Soil Dynamics Research Unit	The laboratory was invited to present at an Alabama Agricultural Experiment Station's virtual field day about cover crop mixtures preceding corn. The presentation was recorded and posted to an Alabama Agricultural Experiment Station Facebook page. Currently, there have been more than 1,000 views and more than 300 views of the presentation.
AL	Soil Dynamics Research Unit	The laboratory was invited to present at the 2019 Alabama Row Crops Short Course about Cover Crops for Peanut Production Systems. Participants were growers, industry reps, and other researchers. There were approximately 150 attendees.

AL	Soil Dynamics Research Unit	The laboratory was invited to present management information about cover crops to Alabama Farmer's Cooperative (AFC) representatives and local growers as part of an information meeting to participants about cover crops. The meeting was at a field site where AFC has a cover crop field demonstration. There were approximately 40 attendees
AL	Soil Dynamics Research Unit	The laboratory was invited to present at the 2020 Louisiana Agricultural Technology & Management Conference about Cover Crop Management. Participants were ag consultants, industry reps, and other researchers. There were approximately 150 attendees.
AL	Dale Bumpers Small Farms Research Center	Attended the Southern Sustainable Agriculture Working Group Conference and presented two posters: (1) organic compared with conventional systems for lamb production yield differences in performance in southeastern U.S. pastures and (2) estimating the value of parasite resistance in sheep.
AR	Poultry Production and Product Safety Research Unit	The laboratory had a presentation on the economic and environmental impacts from pasture Best Management Practices (BMPs) at the Beaver Watershed Alliance's Pasture Aerator and Discovery Farm field day. Presented to approximately 30 producers interested in implementing on-farm conservation practices.
AR	Poultry Production and Product Safety Research Unit	The laboratory had a video presentation on understanding soils to understand agroforestry systems at the Soil Survey for Soil and Water Quality's Applications in the Natural State meeting. Approximately 100 producers, professors, industry, stakeholders, and students attended.
AZ	Southwest Watershed Research Unit	The laboratory led a training session on the Automated Geospatial Watershed Assessment (AGWA) tool, along with University of Arizona collaborators. Participants learned how to use AGWA to assess erosion control after fires, design green infrastructure, and perform scenario planning and watershed assessments.

CA	Agricultural Water Efficiency and Salinity Research Unit	The laboratory gave a presentation to the Desert Managers Group on "Evaluating the Efficiency of Drywell for Enhanced Aquifer Recharge."
CA	Commodity Protection and Quality Research Unit	The laboratory presented data on control of navel orangeworm in tree nuts to the industry.
CA	Invasive Species and Pollinator Health Research Unit	The laboratory provided a 1-hour presentation entitled "Plant Physiology, Biology and Ecology: Why Management Works" to a workshop for the East Bay Municipal Utility District. Approximately 40 individuals attended.
CO	Central Plains Resources Management Research Unit	The laboratory presented research results to farmers and researchers at the Crop Production Conference.
DC	Floral and Nursery Plants Research Unit	The U.S. National Arboretum hosted a booth at the Mid-Atlantic Trade Show (MANTS) in Baltimore, MD, where approximately 12,000 attendees from the nursery and allied industries gathered to view products from 900+ vendors. The outcome was meeting new and reconnecting with existing stakeholders and hearing about problems, challenges, and pressing needs of the industry.
DC	Floral and Nursery Plants Research Unit	Scientists from the U.S. National Arboretum gave two talks to growers and researchers at the Southern Nursery Association Research Conference in Baltimore, MD, entitled: (1) "The U.S. National Arboretum - conserving native plants for the American landscape," and (2) "Molecular Variation of *Osmanthus armatus* hybrids."
FL	Citrus and Other Subtropical Products Research Unit	The laboratory presented research finding to University of Florida's Indian River Research and Education Center.
FL	Subtropical Horticulture Research Unit	The laboratory gave a presentation via Zoom to farmers in Puerto Rico and the Dominican Republic as well as an employee of a government agriculture organization of the Dominican Republic. The presentation gave diagnostic and management information for diseases found on cacao in Puerto Rico, with a focus on a virus recently found on the island.

IA	Agrosystems Management Research Unit	The laboratory gave a presentation at the Field to Market (FtM) General Assembly, during a concurrent session to update FtM members on the FtM Science Advisory Council and its activities. Presented on research challenges to updating the Water Quality component of FtM's Sustainability Metric.
IA	Agrosystems Management Research Unit	The laboratory gave the virtual presentation "Supporting NRCS use of the Agricultural Conservation Planning Framework in Priority National Water Quality Initiative Watersheds" to the Iowa Chapter of the Soil and Water Conservation Society during the chapter's summer meeting.
IA	Agrosystems Management Research Unit	The laboratory gave the presentation "Practices to Reduce the Loss of Nutrients and Sediment Through Tiles: Tile Inlet Filters, Bioreactors, and Saturated Buffers" at the North Central Iowa Crop and Land Stewardship Clinic, Iowa Falls, Iowa. Producers and extension specialists were in attendance.
IA	Agrosystems Management Research Unit	A laboratory scientist was a speaker and panelist at a workshop on "Connecting Soil Health and Watershed Health" which was hosted by the Foundation for Food and Agricultural Research (FFAR) on "Linking Soil and Watershed Health to In-field and Edge-of-Field Water Management" in Morgantown, WV.
LA	Honey Bee Breeding, Genetics, and Physiology Research Unit	In conjunction with the Louisiana Beekeepers Association, the Baton Rouge Bee Lab hosted its 23rd annual Field Day. Sessions were offered for beginning, intermediate, and advanced beekeepers with topics such as bee biology, basic equipment, honey bee nutrition, managing colony defensiveness, colony evaluation, swarming, splits, managing varroa, and queen rearing and selection.

LA	Honey Bee Breeding, Genetics, and Physiology Research Unit	The laboratory participated in a webinar for Apiculture Online: Hive Chat with North Carolina State University. The event was live streamed on YouTube. A few hundred beekeepers viewed the 1 hour stream. The event can be seen at https://www.youtube.com/watch?v=uvb6ZmZzcCM
LA	Sugarcane Research Unit	The laboratory had a presentation on weed control research at the Louisiana Agricultural Technology & Management Conference in Marksville, LA. The meeting was attended by approximately 50 scientists, industry personnel, and crop consultants. The presentation title was "Itchgrass and Italian ryegrass management."
LA	Sugarcane Research Unit	The laboratory had a presentation on its research at the American Society of Sugar Cane Technologists Meeting - Louisiana Division in Baton Rouge, LA. The meeting was attended by approximately 50 scientists, sugarcane producers, and industry personnel from Louisiana, Florida, and Texas. The presentation title was "Effect of burning postharvest residue on weed seed mortality after sugarcane harvest."
LA	Sugarcane Research Unit	The laboratory had a presentation on its research at the Extension/Research Sugarcane Training Meeting in Houma, LA. The meeting was attended by approximately 25 scientists, members of the American Sugar Cane League, and Louisiana State University County Extension agents. The presentation title was "Paraquat plus residual herbicides for managing itchgrass in plant-cane."
MD	Animal Genomics and Improvement Laboratory	The laboratory participated in an International Committee for Animal Recording Functional Traits Working Group meeting to discuss international standards for data recording and genetic evaluation.
MD	Animal Genomics and Improvement Laboratory	The laboratory participated in the National Dairy Herd Information Association Board Meeting in Rosemont, IL, to discuss industry research needs.

MD	Animal Genomics and Improvement Laboratory	The laboratory participated in a conference call with the American Angus Association team about selection goals.
MD	Animal Genomics and Improvement Laboratory	The laboratory attended the annual meeting of the National Dairy Herd Information Association and gave an invited presentation on its research.
MD	National Agricultural Library (NAL) Digitization and Access Branch	Presented talk on the life and collection of J. Horace McFarland, printer, horticulturalist, writer, and conservationist.
MD	NAL Information and Customer Services Branch	Provided multiple training to various USDA agencies (ARS, FAS, FS, APHIS, NIFA, FNS, AMS, NRCS and FFAR) on DigiTop and NAL resources (journals, databases, news sources), services (document delivery), and EndNote reference management software.
MD	NAL Information and Customer Services Branch	NAL and Nutrition.gov teamed provided outreach with information, answering questions, demonstrations, and distributed information materials to attendees at the Public Libraries Association Conference 2020.
MD	NAL Information and Customer Services Branch	Completed multiple workshops and webinars remotely on Meeting the Information Requirements of the Animal Welfare Act to various stakeholders (Centers for Disease Control, Food and Drug Administration, Purdue University, University of Tennessee, Naval Medical Center, and American Association for Laboratory Animal Science).
MD	Natural Resources and Sustainable Agricultural Systems	The laboratory presented on current ARS research on ammonia emissions from agricultural activities at the Fall Meeting of the National Atmospheric Deposition Program. There were about 70 people in the audience from Federal agencies, State agencies, and universities.
MD	Natural Resources and Sustainable Agricultural Systems	The laboratory presented a virtual talk on its research at the Conservation and Drainage Network meeting. There were 115 participants from universities, private groups, and other Federal agencies.

MD	Natural Resources and Sustainable Agricultural Systems	Laboratory gave the presentation “Tying it All Together for Innovation in Conservation” at the National Association of Conservation Districts Annual meeting to 125 attendees.
MD	Natural Resources and Sustainable Agricultural Systems	Laboratory gave a presentation to 5,000 industry participants at the Environmental Systems Research Institute (ESRI) Fed Conference on Partners in Data Innovation.
MI	Sugarbeet and Bean Research Unit	Laboratory participated in an online virtual field day for the research station where trials are conducted. Michigan State University Extension organized, took video, and ran the event.
MN	Soil Management Research Unit	Laboratory gave an invited presentation on soil health at the Minnesota Seeding Contractors Association’s Annual Meeting held in St. Cloud, MN.
MN	Soil Management Research Unit	Laboratory conducted an online presentation and demonstration on soil health for the Main Street Project's Climate Land Leaders. The title of the presentation was “What is soil health and how can we measure it?”
MN	Soil Management Research Unit	Laboratory gave an invited presentation entitled "The low-down on soil amendments" and gave a hands-on demonstration of earthworm dynamics at the 2019 Conservation Tillage Conference held in St. Cloud, MN. The event was sponsored by the University of Minnesota Extension.
MT	Range and Livestock Research Unit	ARS researchers presented research topics to the local producers and landowners. The range tour was coordinated by the MSU Extension Prairie County office.
MT	Range and Livestock Research Unit	Laboratory invited by the MT Red Angus Association to present "Are there other management practices I can effectively use for young cow reproduction?” during two sessions at the MT Stockgrowers Association’s Mid-winter meeting.

NC	Plant Science Research Unit	Laboratory presented summary of modern breeding methods to Environmental Protection Agency and American Seed Trade Association meeting on plant breeding technology.
ND	Healthy Body Weight Research Unit	Laboratory participated in a roundtable discussion with University of North Dakota graduate students in nutrition about working in nutrition research, particularly human nutrition research.
NM	Range Management Research Unit	Laboratory conducted multiple Virtual LandPKS Training Part II for EcoCycle Community Carbon Farming Coordinators, Grameen Foundation Project, South Dakota Ranchers (BeefSD program), Stonyfield milk suppliers, and USAID.
NM	Range Management Research Unit	Laboratory held a Field Day focused on "Novel strategies for sustainable livestock production in arid rangelands." Field day highlighted collaborative research on the use of heritage cattle types, precision technologies, and decision-support tools that are aimed at sustaining production and minimizing costs and the environmental footprint of beef production in arid lands.
NM	Range Management Research Unit	Laboratory gave the keynote address on climate change adaptation and social marketing at the NM Farmers Marketing Association. Also curated two Science on a Sphere presentations.
NM	Range Management Research Unit	Laboratory presented in a webinar series for the Bureau of Land Management's Assessment, Inventory, and Monitoring (AIM) project leads and data users that described the process of using AIM data for ecological site development.
NM	Range Management Research Unit	Laboratory held a virtual workshop at Grassland Expo for front range ranchers open space managers.
OH	Application Technology Research Unit	Laboratory hosted a demonstration for 72 Ohio Farm Bureau staff and leadership members on how the intelligent sprayer technologies can reduce pesticide use, increase production profits, and safeguard the environment for growers.

OH	Application Technology Research Unit	Laboratory gave a presentation on weed control for landscapes and field nurseries at the 2020 Kentucky Nursery and Landscape Association Educational Outing and Expo in Louisville, KY.
OH	Application Technology Research Unit	Presented Virtual Grower at the Local Agricultural Marketing Program's annual meeting in Riverhead, NY
OH	Soil Drainage Research Unit	Laboratory gave a presentation titled "USDA-ARS Edge-of-Field Research: Results and Future Direction" at Science and Solutions meeting in Fort Wayne, IN. Attended by 32 State and Federal agencies and university and Lake Erie stakeholders.
OH	Soil Drainage Research Unit	Laboratory gave presentation titled "Finding the Balance between Sacred Cows and Sacrificial Lambs (Environmental vs Agronomic Practices)" to an audience of 30 policy, extension, practitioner, and NGO stakeholders.
OH	Soil Drainage Research Unit	Laboratory gave a presentation titled "USDA-ARS, Edge of Field Research in Ohio" to approximately 60 State and national agency and Great Lake's stakeholder representatives at the annual Great Lakes Regional Sediment Management Workshop, at the Army Corp of Engineers offices in Chicago, IL.
OH	Soil Drainage Research Unit	Laboratory gave a presentation on the impacts of drainage water management on addressing water quality issues to more than 75 extension educators, producers, researchers, and Lake Erie stakeholders at the Conservation Tillage and Technology Conference (Ada, OH).
OH	Soil Drainage Research Unit	Laboratory gave a presentation on edge-of-field data to a group of NRCS, Ohio Soil and Water Conservation Districts, Farm Bureau, and other farming related group personnel at the Federation of Ohio Soil Water Conservation Districts annual meeting.

OH	Soil Drainage Research Unit	Laboratory gave a presentation on what is more important for water quality, recently applied P or legacy soil P, at the Conservation Tillage Conference in Ada, OH.
OH	Soil Drainage Research Unit	Laboratory gave a presentation titled "Research Update: Using Drones (UAVs) to Map Subsurface Drainage" at the virtual 2020 Conservation Drainage Network Annual Conference. This meeting was attended by university, government, and industry personnel.
OH	Soil Drainage Research Unit	Laboratory gave a presentation titled "Research Update: Using Drone Aerial Imagery for Drainage Mapping" at the 2020 Ohio Land Improvement Contractors Association (OLICA) Annual Meeting in Dublin, OH
OK	Great Plains Agroclimate and Natural Resources Research Unit	Laboratory attended and participated in the Southwest Beef Symposium held in cooperation with New Mexico State University and Texas A&M University, which is part of the Sustainable Southwest Beef Cross Agency Project. Laboratory scientists interacted with participants (including ranchers, exhibitors and speakers), answered questions, and manned the exhibit table.
OK	Great Plains Agroclimate and Natural Resources Research Unit	Laboratory hosted the Long Term (LTAR) Regionalization and Unmanned Aerial Systems (UAS) Workshop. The group finalized development of the first manuscript to be produced by the Remote Sensing /Geographical Information Systems Working Group, had discussions concerning collaborative network-wide research projects, integration of remote sensing technologies into UAS platforms, the LTAR Data Innovations project, and a session on working with calibrated UAS data.

OK	Hydraulic Engineering Research Unit	Updated an activity book and developed a "how-to" soil erosion demonstration brochure to be sent to the American Society of Agricultural and Biological Engineers to be used for their social media during distance learning.
OK	Hydraulic Engineering Research Unit	Laboratory hosted an internal erosion workshop.
OR	Horticultural Crops Research Unit	Laboratory was invited to talk about its research program to members of the Idaho State Horticultural Society.
TX	Cotton Production and Processing Research Unit	Laboratory presented on the best practices for safe seed cotton storage in round modules and detection and elimination of plastic contamination in seed cotton at the Red River Crops Conference in Altus, OK. This conference brings together cotton producers and researchers from Texas, Oklahoma, and Kansas to discuss key issues faced by the cotton and grain industries in the region.
TX	Cotton Production and Processing Research Unit	Laboratory presented on cotton fiber quality and detection and elimination of plastic contamination from seed cotton in the ginning process at Cotton Incorporated's Great Plains Cotton Conference in Wichita, KC. This meeting brought together cotton producers and researchers from Texas, Oklahoma, Kansas, Tennessee, North Carolina, and California to discuss issues faced by the cotton industry in the northern-most growing region of the U.S.
UT	Poisonous Plant Research Unit	Laboratory had a booth at the Utah Cattlemen's Association Trade Show.
UT	Poisonous Plant Research Unit	Laboratory participated in the Converse (Wyoming) County Weed & Pest Growers Annual Meeting.
WA	Physiology and Pathology of Tree Fruits Research Unit	Laboratory presented its current postharvest apple research at the Washington Tree Fruit Research Commission research review.

WA	Physiology and Pathology of Tree Fruits Research Unit	Laboratory described results from its recent research on postharvest biology of pear fruit at the Pacific Northwest NW Pear Committee annual research review in Yakima, WA. Presentations described how new techniques could support enhanced fruit quality and reduce losses after long-term cold storage of pear fruit.
WA	Physiology and Pathology of Tree Fruits Research Unit	Laboratory gave presentations describing its recent research at the Washington State Fruit Association Annual Meeting.
WA	Temperate Tree Fruit and Vegetable Research Unit	Laboratory participated in Washington State University's Prosser's Centennial celebration and educated community members and local students on the important research being conducted by its scientists, specifically teaching them about the potato breeding and pathology programs.
WI	Vegetable Crops Research Unit	Laboratory presented its research results to potato farmers.
WI	Vegetable Crops Research Unit	Laboratory performed two hands-on workshops focused on its research to improve potato genetics. The workshop discussed potato cultivation in general and led hands-on experiments to determine the effect of increased sugar content in potatoes on fry color and the identification of virus-infected plants using commercially available test strips.
WV	Innovative Fruit Production, Improvement and Protection Unit	Laboratory presented its research on the invasive spotted lanternfly to the West Virginia Invasive Species Working Group that includes State Dept of Agriculture personnel, regional IPM, and university specialists.
WV	Innovative Fruit Production, Improvement and Protection Unit	Laboratory taught a grafting workshop at the Shepherd University Agricultural Innovation Center at Tabler Farms in Shepherdstown, WV. The goal was to educate the participants on the uses of grafting and why it is important in horticulture. They can now graft fruit trees in their own back yards or farms after this workshop.

WV	Innovative Fruit Production, Improvement and Protection Unit	Laboratory taught a pruning workshop at the Air Guard Base in Charleston, WV. The goal was to educate the participants on how to prune and maintain fruit trees, mainly apple trees in their own back yards or farms

3.8. FY 2019 Technology Transfer Award Winners

ARS Technology Transfer Award

Scientists: Terry Arthur and Tommy Wheeler, Meat Safety & Quality Research Unit (Clay Center, NE)

Title: Beef Trim Sampling Methods Team

Federal Laboratory Consortium for Technology Transfer (FLC) Awards

Laboratory: Coastal Plain Soil, Water and Plant Conservation Research Unit (Florence, SC)

Title: Odor/Ammonia Capping of Swine Lagoons using High Performance Nitrifiers

Award: National, Excellence in Technology Transfer

Laboratory: Soil and Water Management Research Unit (Bushland, TX)

Title: Sensor Based Variable Rate Irrigation Control Increases Crop Water Productivity

Award: National, Excellence in Technology Transfer

Laboratory: Soil and Water Management Research Unit (Bushland, TX)

Title: Sensor Based Variable Rate Irrigation Control Increases Crop Water Productivity

Award: National, Technology Focus Award

Person: Robert J Griesbach

Award: National, Harold Metcalf FLC Service Award

Person: Robert J. Griesbach

Award: Mid-Atlantic Region, Outstanding Technology Transfer Professional

Laboratory: Office of Technology Transfer (Beltsville, MD)

Title: Innovation Fund Grant Program

Award: National, Technology Transfer Innovation Award

Laboratory: Produce Safety and Microbiology Research Unit (Albany, CA)

Title: Reversible Antimicrobials: A Strategy to Reduce Ecotoxicity and Antibiotic Resistance

Award: Far-West Region, Outstanding Technology Development

Laboratory: Soil and Water Management Research Unit (Bushland, TX)

Title: Sensor Based Automatic Variable Rate Irrigation Control for Greater Crop Water Productivity

Award: Mid-Continent Region, Excellence in Technology Transfer

Laboratory: Coastal Plain Soil, Water and Plant Conservation Research Unit (Florence, SC)

Title: Odor and Ammonia Capping of Swine Lagoons Using High-Performance Nitrifiers

Award: Southeast Region, Excellence in Technology Transfer

3.9. Selected Metric Charts.

Figure 1. Number of new and active CRADAs and MTRAs.

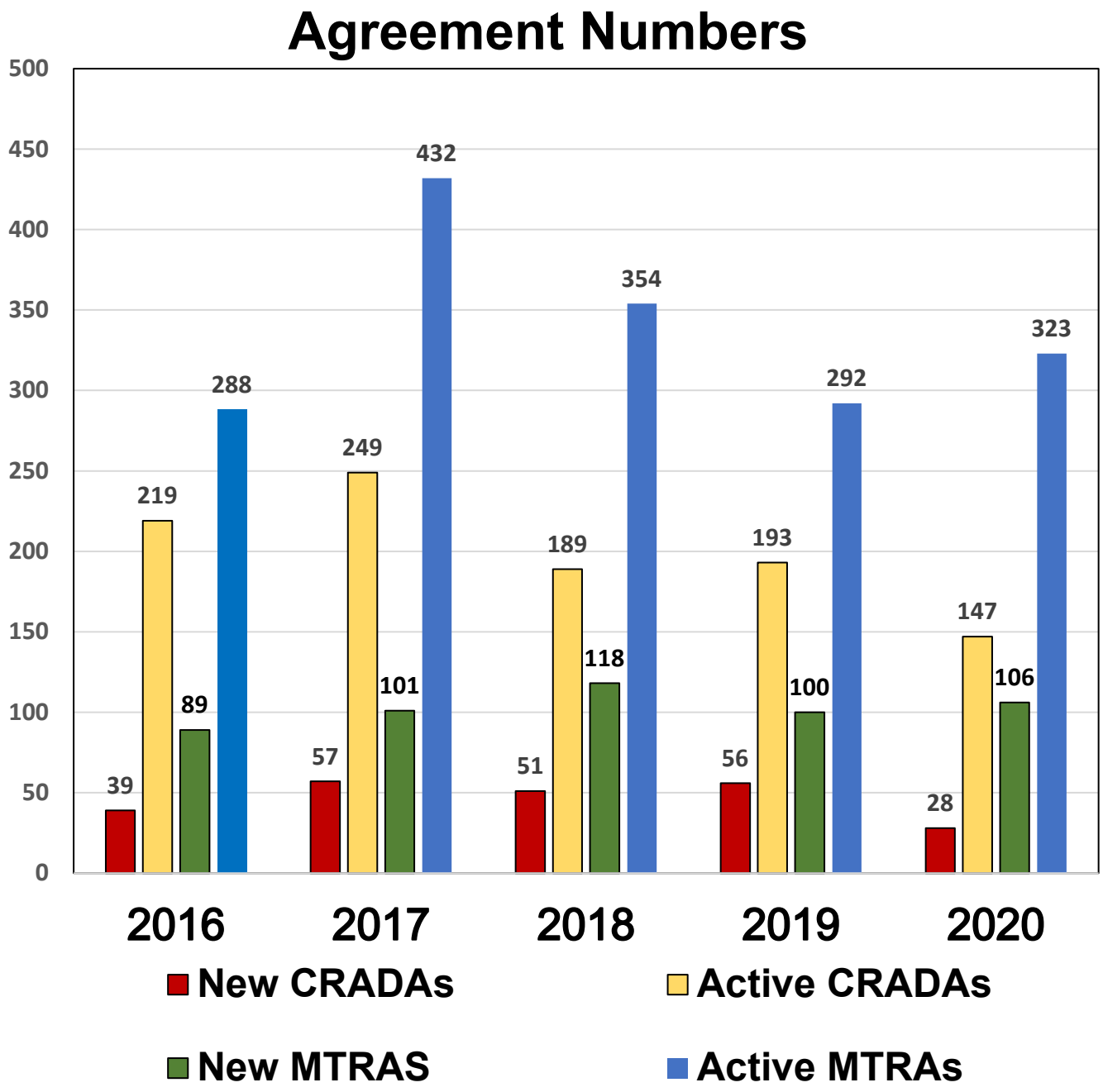


Figure 2. Number of collaborative research agreements (CRADAs, MTRAs, and other agreements, including Trust Fund Cooperative Agreements, Reimbursable Agreements, Interagency Agreements, and Non-Funded Cooperative Agreements) executed by type in FY 2020.

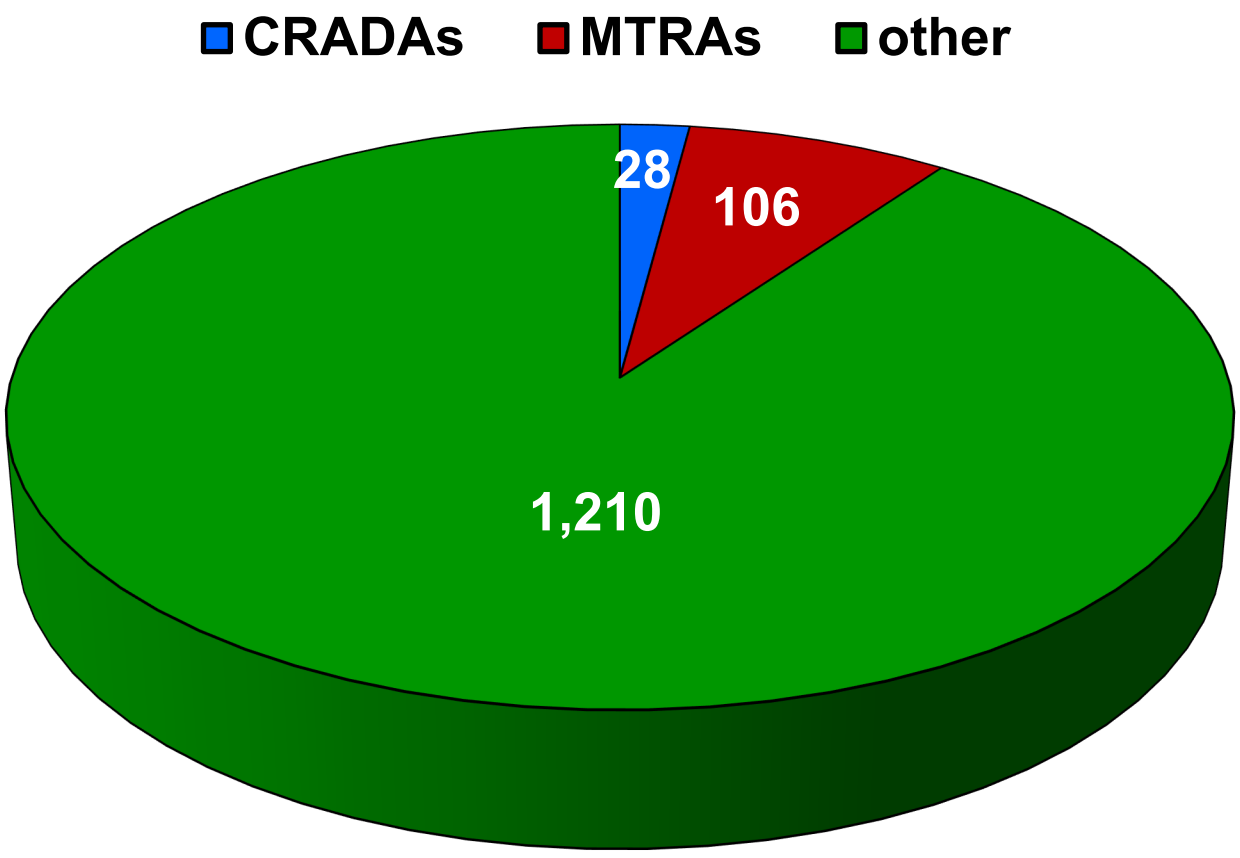


Figure 3. Number of invention disclosures, patent applications filed, and patents issued. The year in which a patent issues is not the year in which the patent is filed. The increase in the number of invention disclosures in FY 2018 was the result of a significant increase in biological materials disclosures.

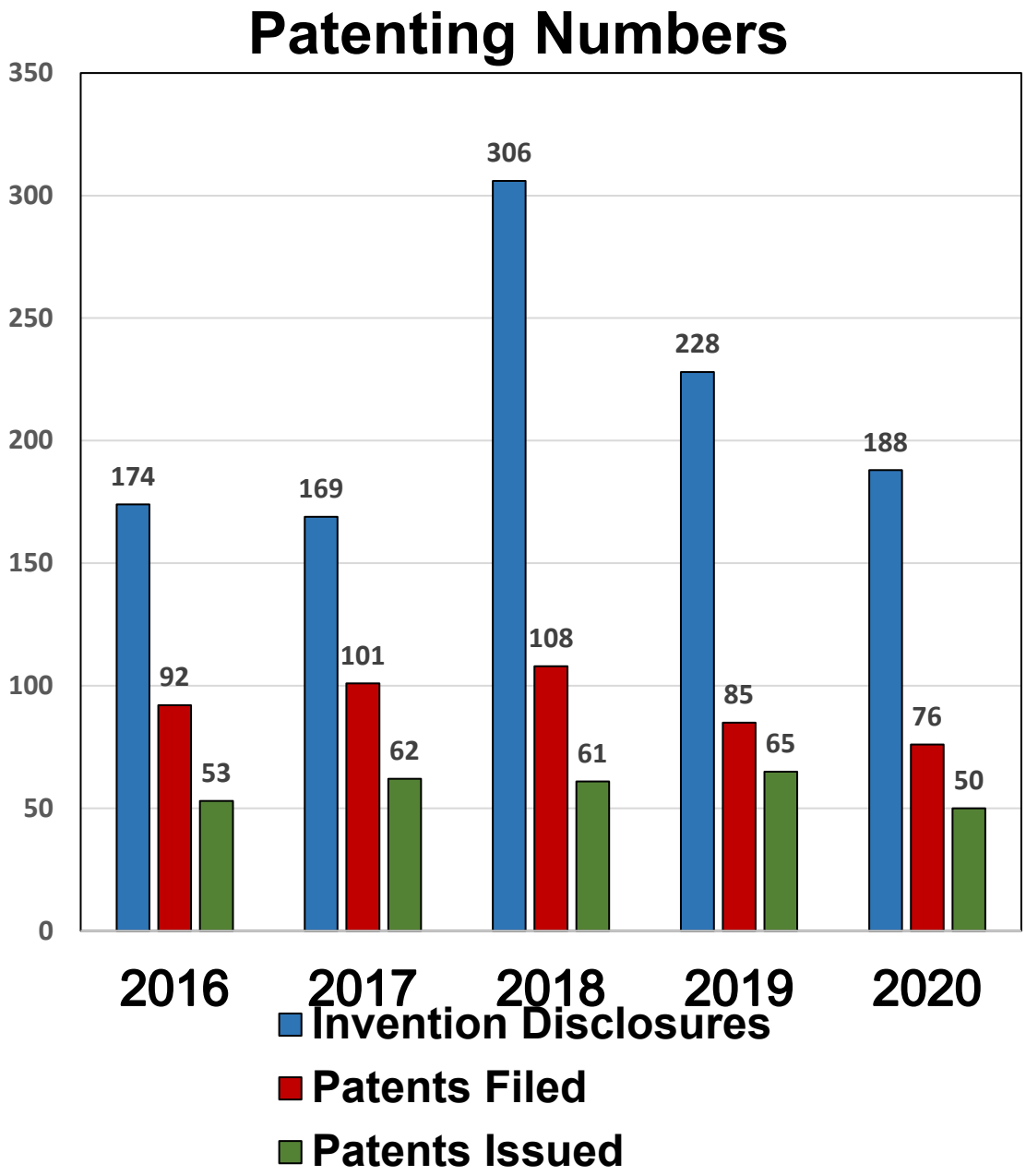


Figure 4. Percentage of patents issued in FY 2020 by scientific discipline.

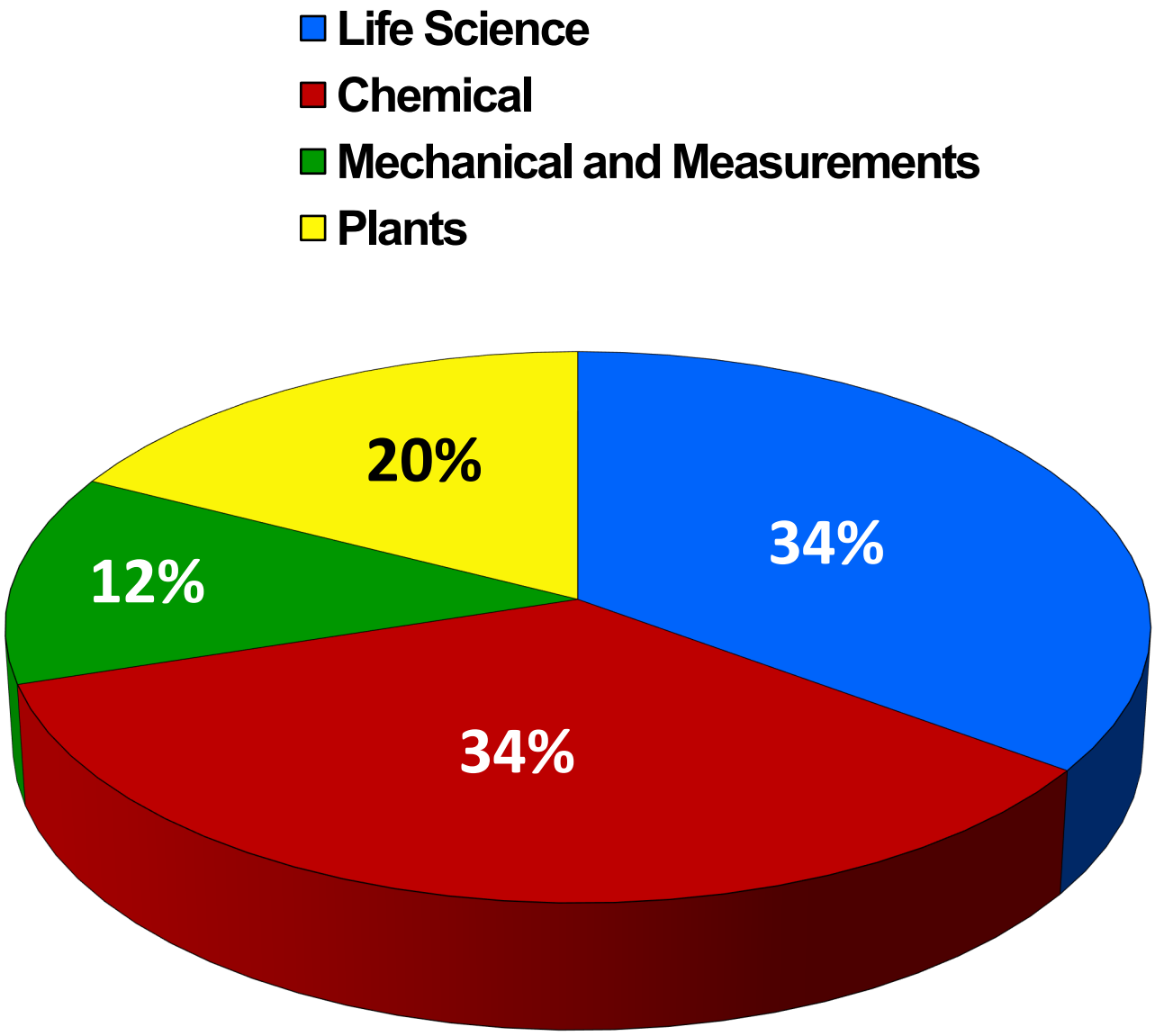


Figure 5. The ratio of patents issued over patent applications filed per year. Although the year in which a patent is issued is not typically the year in which the patent application is filed, over time the ratio of patents issued over the number of patent applications filed is an indicator of "judicious" patenting. Over the last 5 years, this indicator suggests that ~62 percent of the patent applications result in an issued patent.

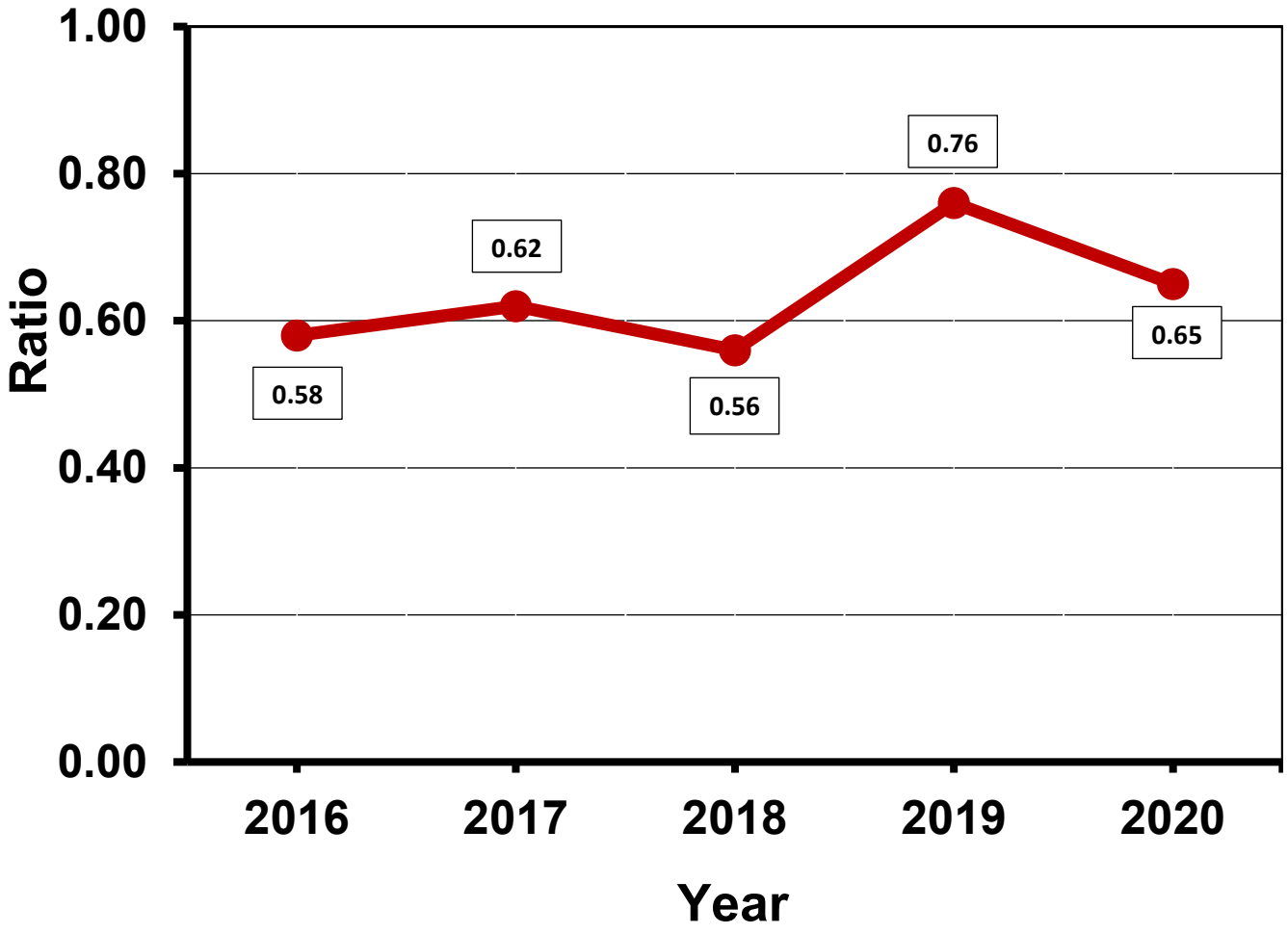


Figure 6. Number of license types per year

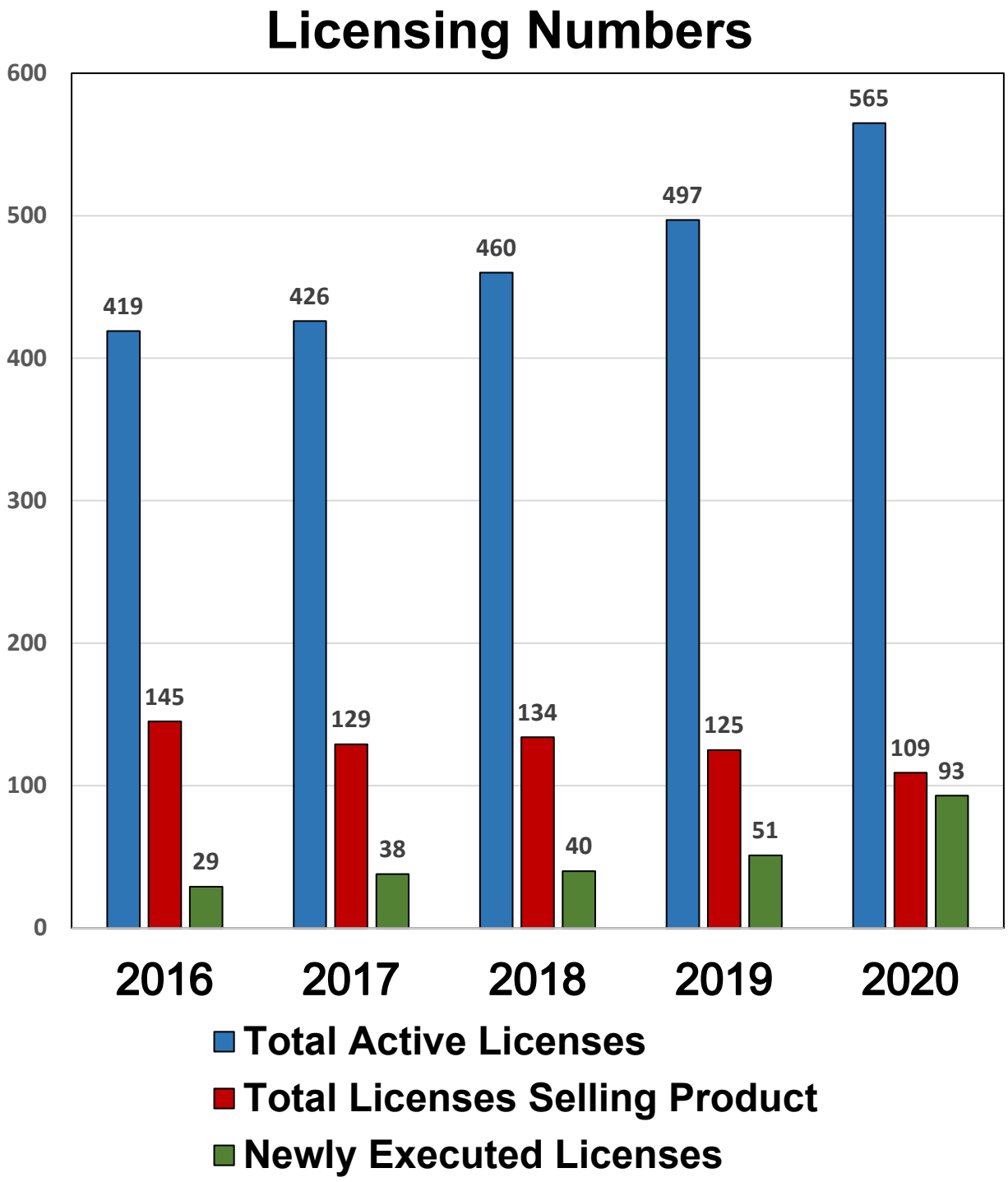


Figure 7. Earned license royalty income (ERI) over time. The lower income in FY 2018 and FY 2020 was due to several of the top revenue generating licenses expiring in FY 2017 and 2019.

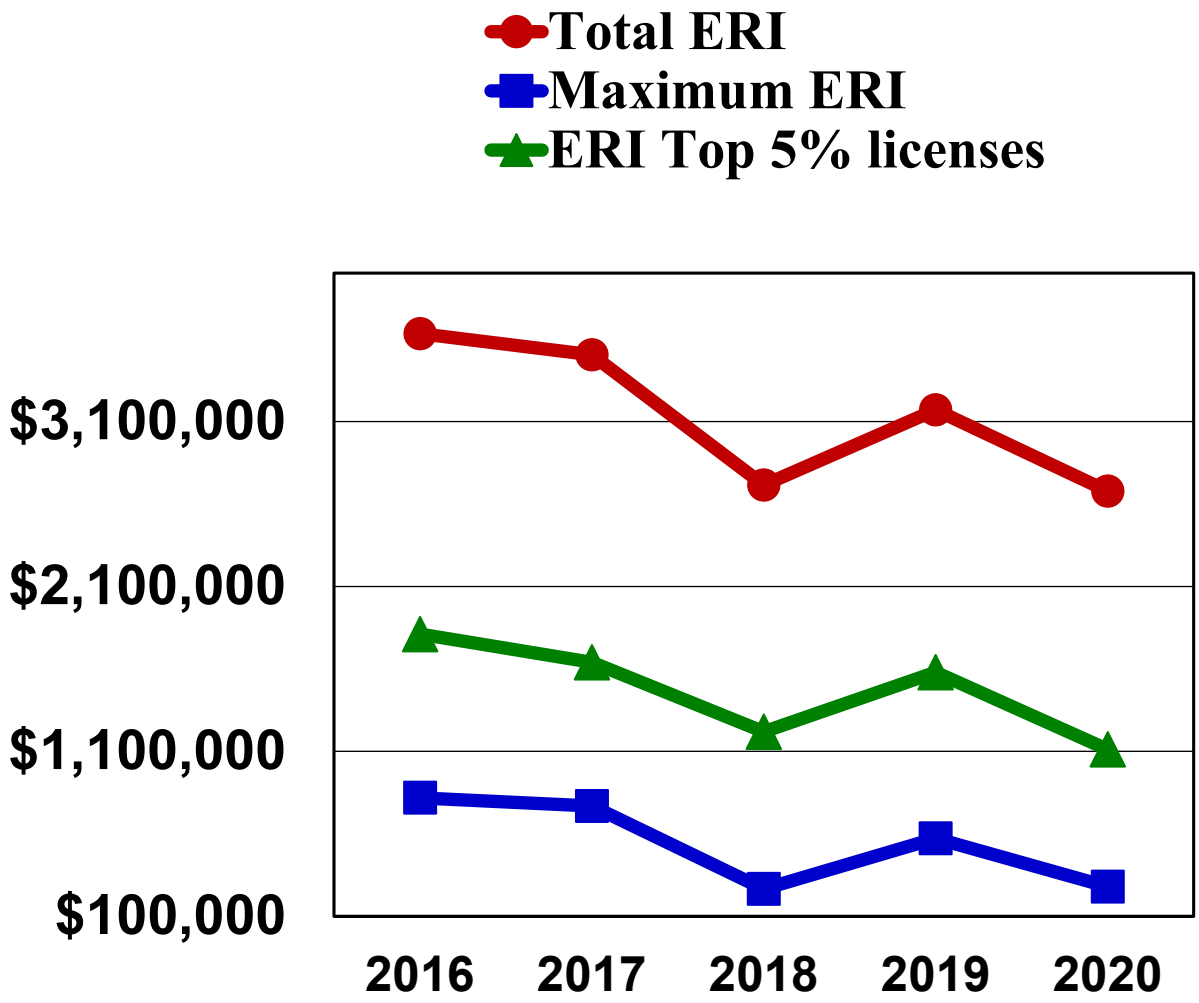


Figure 8. The percentage of new licenses executed in FY 2020 by business type.

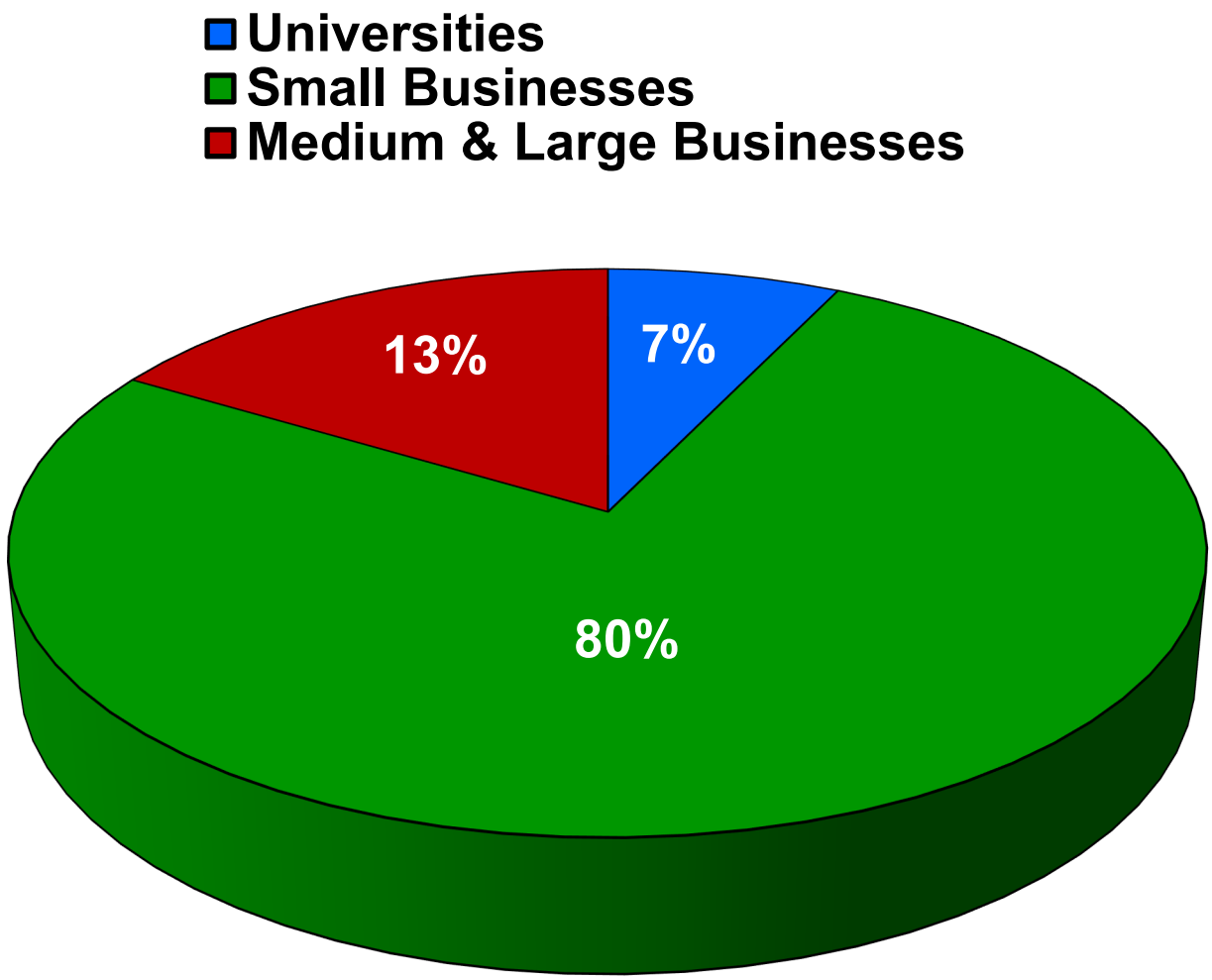


Figure 9. The ratio of newly signed invention licenses over newly issued patents per year. Although the year in which a license is signed is not typically the year in which the patent has issued, over time the ratio of newly signed licenses over the number of newly issued patents is an indicator of "judicious" patenting contemplating among other things commercial viability of the technology.

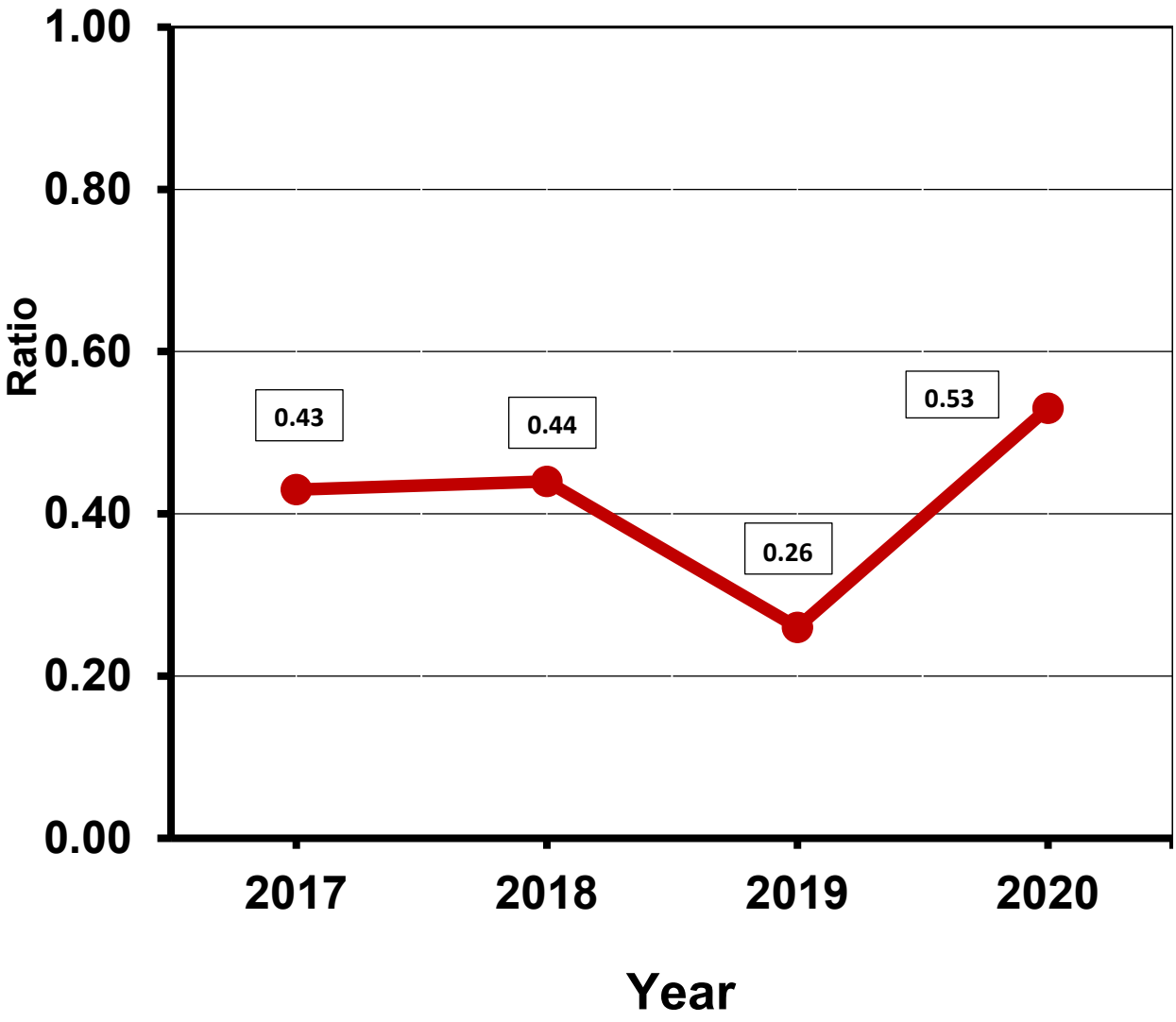
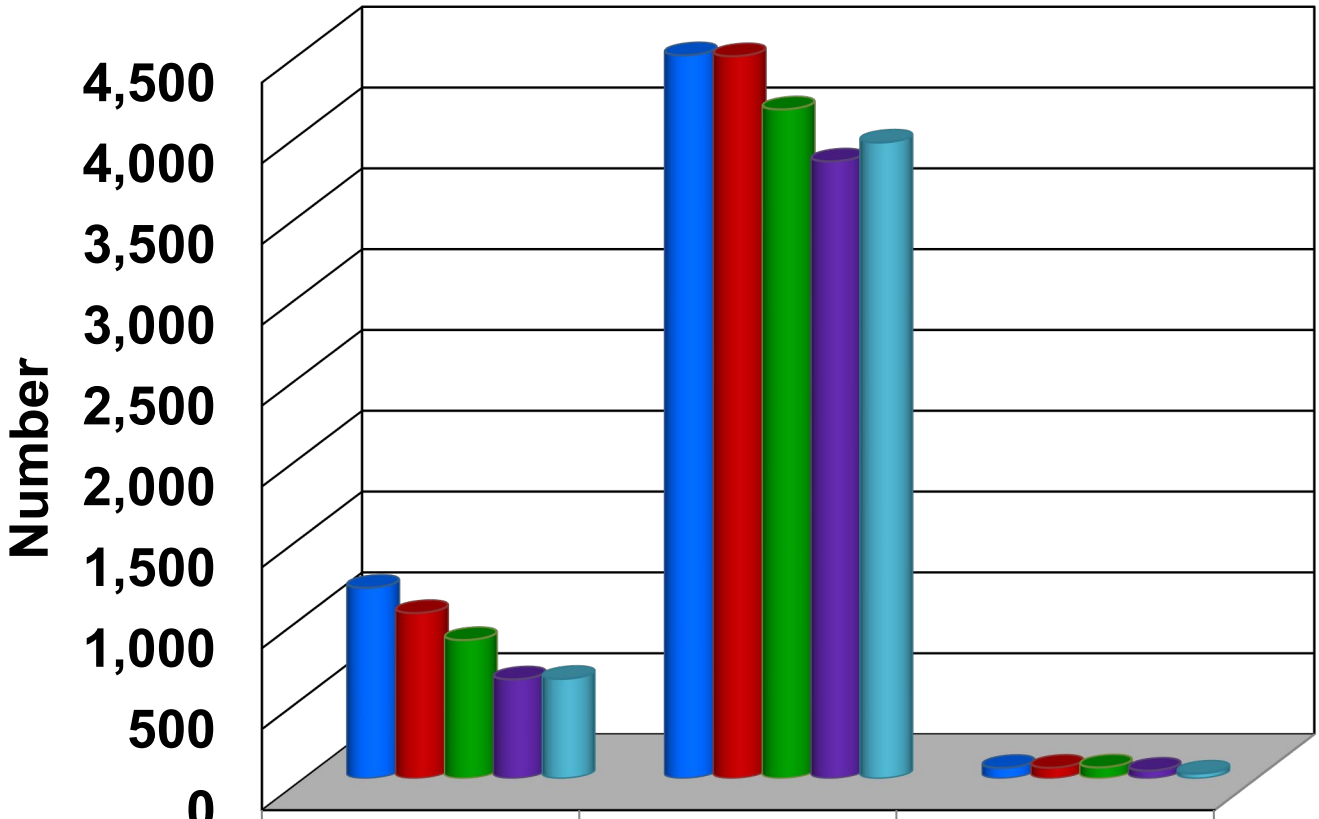


Figure 10. Number of publications per year



	Meeting Abstract	Scientific Journal	Trade Journal
2016	1,178	4,473	65
2017	1,022	4,467	66
2018	855	4,138	68
2019	612	3,816	48
2020	615	3,933	30

4.0. Economic Research Service (ERS)

4.1. Mission Statement

ERS's mission is to conduct economic research and develop data and statistics that inform public program and policy decisions related to agriculture, food, the environment, and rural development.

4.2. Nature and Structure of Research Program

ERS follows the general USDA definition of technology transfer as the adoption of research outcomes for public benefit and, to that end, conducts relevant and objective economic research and policy analyses that inform program and policy decisions. ERS designs its research to demonstrate the consequences of taking alternative policy or programmatic pathways. The agency's data and market analysis program provide crucial market and trade outlook information to help farmers and agricultural companies run successful businesses and support jobs.

ERS is the primary source of statistical indicators that, among other things, gauge the health of the farm sector (including farm income estimates and projections), assess the current and expected performance of the agricultural sector (including trade), and provide measures of food insecurity in the United States and abroad. ERS is one of 13 officially designated (by the Office of Management and Budget) Federal Statistical Agencies.

ERS disseminates its research findings, market information, and statistical indicators in a variety of outlets including:

- Its website (www.ers.usda.gov);
- Its online magazine, *Amber Waves*;
- Outlook reports for specific commodity sectors
- Research and information reports;
- Data products, in a variety of forms/formats to suit users' needs; and
- Refereed journal articles, which ensure the professional credibility of findings.

ERS is located in Kansas City, MO, and Washington, DC and employs researchers working on economic and related social science research. Additionally, ERS seeks out academic and private-sector collaborators through contracting and cooperative agreements to leverage external expertise to complement the knowledge of our intramural research staff.

4.3. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)

ERS uses a web-centric approach to communication with customers in order to convey clear, objective, and transparent research, data, and analysis to decisionmakers, policy officials, industry, non-governmental organizations, and the general public. All ERS research, data, and other information disseminated by the agency are available through the ERS website. ERS's major FY 2020 information technology (IT) accomplishment was successfully migrating its IT resources and staff support to the Office of the Chief Information Officer's Client Experience Center. ERS measures success of the ERS website and its products and services using a variety of web analytics tools and sources to assess performance, quality, reach, relevance, and impact (Adobe Analytics, Google Digital Analytics Program, Site Improve, Search, Constant Contact, and the Foresee American Customer Satisfaction Index/ACSI survey). The ACSI tracks satisfaction of website users and provides a basis for comparison with similar Government and private-sector websites. The target for this measure is at or above the average rating for Government websites in the Information/News category.

4.4. Strengthening Current Activities

ERS continues to enhance and update its website. Upgrades made this fiscal year provided improved performance (website is faster, more resilient), security, and efficiency in publishing. New features included simpler, more intuitive navigation; enhanced functionality for mobile users; and improved data dissemination, with new, more interactive user interfaces and new data APIs (Application Programming Interfaces) to enhance information delivery to customers. ERS's concerted efforts also improved on-time posting 5 percentage points to 95 percent and website Section 508 Accessibility by 39 percentage points.

ERS continues to make use of social media and new technologies (such as mobile-responsive/device-agnostic and Open Data methodologies) to widen and expand the reach of our information services to the general public. ERS has been a leading innovator in support of Open Data initiatives, providing a wealth of products—including data and information—designed to enhance mission delivery. In FY 2020, ERS continued expanding the use of several tools designed to help consumers more easily access critical programs and stimulate further innovation:

- **ERS's Twitter feed** continues to expand the audience for ERS information, growing to over 35,000 followers in FY 2020—up from 32,000 followers in FY 2019 and 29,000 followers in FY 2018. See https://twitter.com/usda_ers

- **Responsive, Device-Agnostic Design:** ERS continued to optimize its website for mobile users, providing fast, easily navigable, mobile-friendly pages that automatically adapt to the user's computer, tablet, and smartphone —ensuring the website is available anywhere, anytime, from any device. This method also provides internal efficiencies in design/production (versus developing multiple style sheets for individual devices/platforms).

- **Data Visualizations:** ERS continued to offer data visualizations via interactive charts, maps, and graphs to more effectively deliver data in ways that are more meaningful, useful, and easier for customers to use.

- ERS also continued to provide daily **Charts of Note**, with easily digestible research highlights, sent by email to subscribers and posted to the website. ERS updates the **Ag and Food Statistics: Charting the Essentials** quarterly, providing the basics of food, farming, and rural America via a series of charts and maps covering key information about the farm and food sectors, including agricultural markets and trade, farm income, food prices and consumption, food security, rural economies, and the interaction of agriculture and natural resources.

- **Web content APIs** (Application Programming Interface), offering digital professionals dynamic access to and a machine-readable option for accessing publications, charts, and other website content. ERS also provides programming tools ("widgets," pre-built off the APIs) that enable digital professionals to easily embed charts from the ERS webpage (such as the popular daily Charts of Note) into their websites/projects.

- **APIs for select data and geospatial/mapping applications**, enabling researchers and developers to build applications using ERS data and processes for additional insights.

- **Open Source**, making it easier to share data, improve tools and services, and return value. The ERS GitHub provides code-sharing and user notification of updates/changes (internally and externally).

The products and tools/services extend and expand access to ERS research findings, market outlook, and data—making the Agency's information more readily available to and more easily consumable by the

general public. These items enable USDA to meet its Digital Government Strategy goals to ensure high-value services and systems are available anywhere, any time, and on any device.

USDA 30: ERS is exploring new methods for evaluating economic impacts of research collaboration and partnerships between public agricultural research institutions and the private sector.

ERS has developed metrics to quantify the impact of its economic social science research and analysis, including measurement of briefings for senior policy officials, citations of ERS research in Government policy and decision-making documents, technical citations in the scientific literature, media citations, and customer use of information published on the ERS website. These metrics are updated annually and are now a standard component of ERS budget and accomplishments reporting.

4.6. Downstream Outcomes

- ERS has developed a unique source of data on details of Americans' food purchases and acquisitions – USDA's National Household Food Acquisition and Purchase Survey FoodAPS. Two versions of the data are being made available to the public. The restricted version, which contains all the data elements at the individual level, can be accessed by researchers from academic institutions and government agencies through a secure Data Enclave. The public-use version of FoodAPS, that masks identities of survey respondents, enables access by all interested members of the public to the valuable data for research and planning. FoodAPS is designed to fill a critical knowledge gap to

support an evidence-based approach to Federal food assistance policies and programs. It is the only source of data to explain food choice behaviors of Americans that integrates multiple types of information from multiple sources on food, economics, nutrition, health, program participation, and environmental factors. The data are being used to address a range of questions such as where households acquire food in a typical week, which foods they acquire, how much they pay for the food and how the acquired foods match recommendations for a healthy diet. FoodAPS protocol are being improved for the second round to enhance the data quality and accuracy while reducing burden through electronic collection of the information.

- Policymakers and the public are provided with easily accessible data on rural areas and issues through the ERS Atlas of Rural and Small-town America (http://www.ers.usda.gov/data-products/atlas-of-rural-and-small-town-america.aspx). The online mapping tool provides county-level information on over 110 statistical indicators on the people, jobs, agriculture, and county characteristics of rural (nonmetropolitan) America. The Atlas helps State and local decision makers pinpoint the needs of particular areas, recognize their diversity, and develop strategies to build on their assets by using location-based data on population, age structure, race and ethnicity, income, employment, indicators of well-being, and other measures. In FY 2018, the Atlas was updated with the most recent information on veterans, education, migration, and income from the American Community Survey. In FY 2019, the Atlas was updated with the most recent county-level information on population, employment, poverty, veterans, education, migration, and income from the Census Bureau and the Bureau of Labor Statistics. In FY 2020, ERS continued to update the

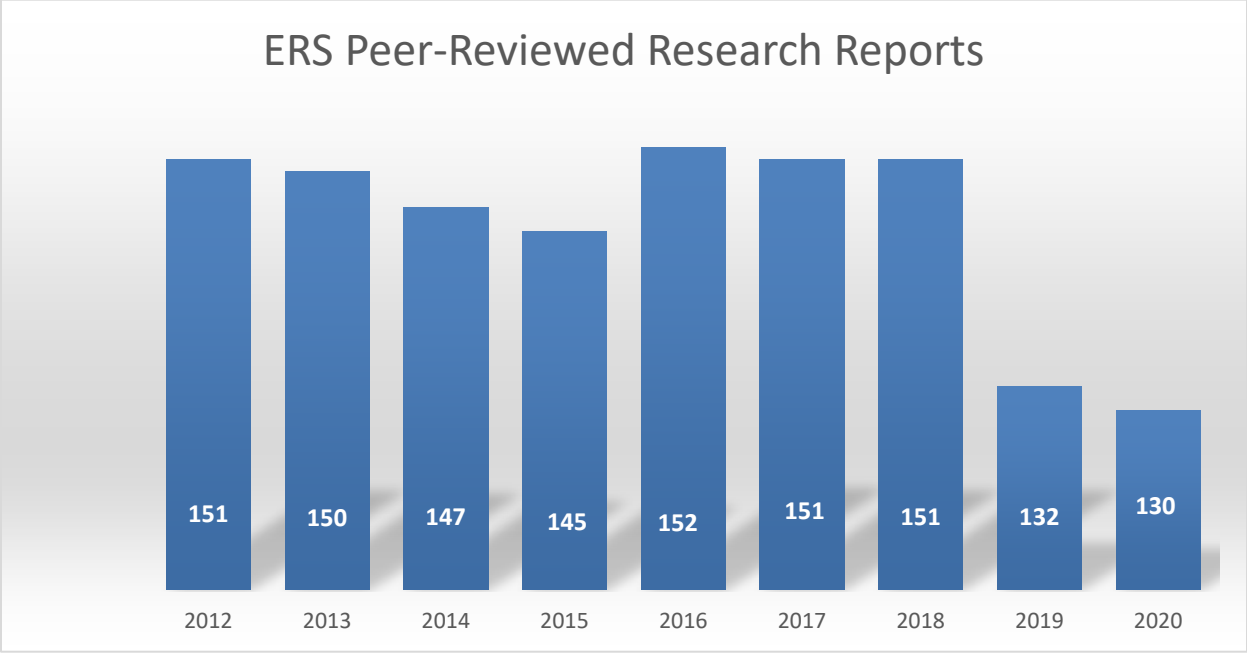
Atlas to include annual unemployment and employment data for 2019. New features were added to improve functionality and users' ability to delineate rural and urban data for reporting and analysis.

- Local officials throughout the country can easily gauge the characteristics of their food environment and target actions that alleviate problems with the availability of healthy food options for the people in their counties or State using the ERS Food Environment Atlas (http://www.ers.usda.gov/data-products/food-environment-atlas.aspx). The Atlas includes over 275 indicators of the food environments in U.S. counties and States – from the number of fast food outlets per capita, to average food prices for various products, and the rate of obesity. Because ERS determined the location and derived the characteristics of neighborhoods that lack access to sources of healthy and affordable food, national, State and local governments can target food access investments so that people with low access will have better choices and better access to healthy, affordable food.

- ERS continued to expand the use of webinars to more directly connect to customers at the time of release of new research and data. As part of the *ERS Insights* Webinar Series, ERS presented 5 webinars in FY 2020 on topics including farm income, rural America, and household food security in the United States. These webinars both inform ERS audiences about complex topics in an easy-to-understand format and also allow participants to ask questions to ERS economic experts. Audiences typically include media, agricultural policy staff, agricultural and financial industry analysts, interest groups, nonprofits, and academia. On average, about 100 people participated in each of these webinars in FY 2020. ERS records, close-captions, and transcribes each webinar and posts them on the website for those who want to view them later.

4.7. Publications

The results of ERS research are freely available on the agency website, provided in a variety of forms and formats. In FY 2020, ERS produced 130 peer-reviewed research reports and Outlook reports (see publications at https://www.ers.usda.gov/publications/).



5.0. Foreign Agricultural Service (FAS)

5.1. Mission Statement

FAS is a trade agency that promotes U.S. agricultural exports.

5.2. Nature and Structure of Program

FAS Washington, D.C. staff and a global network of 93 offices with Foreign Service Officers and locally engaged staff cover 171 countries. FAS supports U.S. foreign policy, identifies problems and provides practical solutions, and works to advance opportunities for U.S. agriculture and global food security. FAS serves as the principal coordinator of USDA's international activities, drawing on the broad expertise of USDA and U.S. agricultural organizations. While FAS does not operate laboratories, conduct research or license technologies, FAS supports adoptions of USDA innovations for public benefit.

Trade Policy

FAS expands and maintains access to foreign markets for U.S. agricultural products by providing expertise in international trade policy negotiations and enforcement, and in working to reduce or eliminate technical barriers to trade and sanitary and phytosanitary trade restrictions. FAS works closely with other USDA agencies, the Office of the U.S. Trade Representative, and other Federal agencies,

State governments, the U.S. agricultural industry, foreign governments, and international organizations to help ensure a level playing field for U.S. agricultural products in the international marketplace.

Market Development and Export Assistance

FAS partners with more than 75 cooperator groups, representing a cross-section of the U.S. food and agricultural industry, and manages a toolkit of market development programs to help U.S. exporters develop and maintain markets for hundreds of U.S. products. FAS also supports U.S. agricultural exporters through export credit guarantee programs and other types of assistance.

Data and Analysis

FAS's network of global contacts and long-standing relationships with international groups contribute to the agency's unique market intelligence capacity for all major agricultural commodities. FAS collects data and its analysts generate objective intelligence on foreign market opportunities, prepare agricultural production forecasts, assess marketing opportunities for U.S. exports, and monitor changes in policies affecting U.S. agricultural exports and imports.

Capacity Building and Development

FAS leads USDA's efforts to help developing countries and emerging market economies improve their food and agricultural systems and participation in agricultural trade. FAS administers international fellowship programs, non-emergency food assistance programs, and other technical assistance.

5.3. Downstream Outcomes

The following summaries illustrate how FAS supported U.S. technology transfers.

IR4 Project, the Global Residue Project, and Global Partnership for Pesticide Standards

Residue data for establishing pesticide maximum residue levels (MRLs) and Codex Alimentarius food safety standards for fruits and vegetables are mostly generated in the United States and other industrialized countries. FAS is leading a Global Residue Project to strengthen the infrastructure and process to establish MRLs. In FY 2020, the Project continued work with stakeholders in 15 partner countries in Africa, Asia, and the Western Hemisphere, where national research teams collaborated on joint residue trials that are based on study protocols and technology models developed by the USDA-funded IR4 Project. By transferring these policy concepts and technical skills to foreign partners, the Global Residue Project has continued coordinating with and complementing the IR-4 Project by supplementing U.S.-generated data and, in some cases, completely shifting the field trial responsibilities for generating pesticide data to partner countries. In addition to economizing U.S. resources for development and commercialization of pesticides, the Global Partnership continued to promote common standards among the U.S. and foreign agricultural trading partners and, overall, provide modern pest

control tools that may be safely used by growers worldwide.

Aflatoxin-Reducing Technologies in Pakistan

In October 2018, researchers, government agencies, and private businesses from the United States and Pakistan participated in a well-publicized launch of the program, *Safer Food through Aflatoxin Control,* in Islamabad, Pakistan. It is estimated that aflatoxin currently contaminates up to 25 percent of crops produced by Pakistan. Through a public-private partnership, led by U.S. company Ingredion and its Pakistan subsidiary Rafhan Maize, this program is paving the way for Pakistani firms to register and use a cutting-edge biological control technology, originally developed by USDA/ARS, to help eliminate aflatoxin contamination of key crops (e.g., grain, nuts, chilies) in Pakistan. This joint effort is already increasing Pakistan's leadership in regional and global efforts to utilize biological control technologies to grow safer crops. This ongoing effort is leading towards the first documented registration and uses of the Aflasafe technology, known locally in South Asia as AflaPak, where it is expected to improve food and feed safety and further strengthen food security for over 200 million Pakistanis over the coming years.

Global Agricultural and Disaster Assessment System (GADAS)

Crop condition assessment datasets, such as satellite-derived vegetation indices, soil moisture status, drought indices, and weather information are mostly generated in the United States and other industrialized countries. Therefore, many less-developed nations struggle to access these datasets, and

accordingly, their assessments of crop conditions, especially after disasters, are delayed and sometimes incomplete. FAS developed GADAS, a web-based geographic information system (GIS) that provides users with free access to key crop condition assessment datasets and GIS tools. Although GADAS was created to aid FAS' global agricultural assessment, it has the extra benefit of helping other countries, particularly less-developed countries, by furthering everyone's understanding of crop conditions, both globally and within countries for local governments.

In FY 2020, FAS initiated geospatial training for crop condition assessments, including the use of GADAS, with agricultural ministry officials in the Dominican Republic, Tanzania, Indonesia, and Peru. Collaborative work also continued with agricultural ministry officials in Honduras and Panama, who were partners in geospatial training in FY 2019. By transferring these crop condition assessment methodologies and geospatial technical skills to foreign partners, FAS strengthens relationships and improves global crop condition assessments by supplementing U.S.-generated data and in some cases, shifting storm-damage assessments to partner countries. For example, Honduras' Ministry of Agriculture, using GADAS tools, completed an assessment of damage from Hurricane Eta within several days after its landfall on November 3, 2020. They shared their damage assessment with FAS, further underscoring the benefits of collaboration.

The sustainability of the program's impact is further enhanced through the integration of local data, as analysts can upload fieldwork datasets to GADAS. For example, agricultural ministry officials in Panama have collected fieldwork data for upland rice, that has been uploaded to GADAS. This data helps train satellite imagery to recognize rice, building a rice classification map for the region of Los

Santos, Panama. This illustrates GADAS' utility as a platform that supports collaborative international data sharing and data generation as analysts integrate their local data with GADAS data.

Among key outcomes this year is demonstrating sustainable partnerships where users have hands-on experience using GADAS and have confidence that FAS supports GADAS into the future. By disseminating information about crop conditions and production, especially with active engagement and collaboration from FAS, this will ultimately help improve users' food and agricultural systems, better inform USDA's international crop production estimates, and facilitate participation in U.S. agricultural trade.

6.0. Forest Service (FS)

The Research and Development (R&D) arm of the USDA, Forest Service is the world's largest forestry research organization combining both basic and applied research aimed at discovering solutions to natural resource problems and creating new tools and knowledge. Forest Service R&D supports the entire forest and natural resources management sector by providing the best available science to the Forest Service, other Federal agencies, State agencies, private landowners, and others for the sustainable management of natural resources nationwide. R&D provides the foundational science for improving forest and grassland conditions for the benefit of both rural and urban communities, so they remain socially, economically, and ecologically viable.

6.1. Understanding

Defining the new Technology Transfer ("tech transfer") and Science Delivery at the USDA, Forest Service R&D with the goal of science delivery to enhance the usefulness of scientific information - "**Pulling together and synthesizing information from a range of disciplines and delivering it in clear and accessible formats to fit user needs**." USDA, Forest Service science is complex, but the need for the research is simple. Land managers, forest managers, city planners, and policy-makers need sound science on all aspects of the natural world and its complex connections with people to make decisions resulting in a healthy and sustainable future for present and future generations of Americans.

The culture of focusing on "science delivery" (and "tech transfer" as a subset of science delivery) is a bit dated. R&D has evolved as a science organization to pursue co-development of knowledge together with practitioners and decision-makers. Science delivery and tech transfer describe a linear process where science is conducted, knowledge is gained by scientists, and then is provided to the end-users as a final step. In contrast, our scientists are bringing knowledge users, stakeholders, and decision-makers into the science process from the very beginning; there are feedback loops. In today's Forest Service, this co-development of knowledge has become central to the research process and helps to increase the relevance of the organization's science findings and tools. This valuable form of science production and application, of which Forest Service R&D is a pioneer, sets the agency apart from universities and other academic institutions. In short, R&D works hand–in-hand with managers to build knowledge together and to design solutions.

6.2. Mission Statement

The overall mission of the Forest Service (FS) is to "sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations." Established in 1905, the FS is an agency of the U.S. Department of Agriculture (USDA) that directly manages 193 million acres of public land in national forests and grasslands and works with State forestry agencies and other partners to assist in managing 491 million acres of State and private forest lands. The FS is the only land management agency in USDA. Gifford Pinchot, the first Chief of the Forest Service, summed up the mission of the Forest Service "to provide the greatest amount of good for the greatest amount of people in the long run." The Forest Service is composed of five areas: National Forest System (NFS),

Research and Development (R&D), State and Private Forestry (S&PF), Business Operations, and Work Environment and Performance.

The R&D leadership's intent is for Research & Development to enhance the rigor and impact of the whole agency. Research provides a seamless connection between the needs of agency's land management mission areas and the latest science. R&D staff are engaged in ensuring the sustained and productive use of our Nation's forest and grasslands, enhancing customer service, and providing a learning core that ensures a positive and productive workplace.

As the world's leader in forestry research, the agency is poised to capitalize on scientific developments, science deliveries, and transfer technologies to help Forest Service scientists:

- gain recognition;
- deliver valued information and knowledge;
- protect intellectual property rights;
- develop research agreements to leverage academic, government and industry partnerships to improve; the health and productivity of our Nation's forests and grasslands;
- inform natural resources policy and land management decisions; and

- anticipate emerging natural resource issues.

R&D scientists are a key part of the Nation's scientific expertise, which includes colleagues in other Federal and State agencies, universities, industry, non-governmental organizations, and even citizens with interest in science. "Citizen Science is defined by the Crowdsourcing and Citizen Science Act of 2017 (5 U.S. Code § 3724) as a form of open collaboration in which individuals or organizations participate voluntarily in the scientific process in various ways, including:

- enabling the formulation of research questions;
- creating and refining project design;
- conducting scientific experiments;
- collecting and analyzing data;
- interpreting the results of data;
- developing technologies and applications;
- making discoveries; and
- solving problems."

A fundamental expectation in the scientific community is that research findings are presented in scientifically credible forums, and that scientific publications resulting from research will undergo review by other scientists to ensure the scientific rigor of the work. Once the reviewed research is published as "scientific literature," the science-based information from those publications must be made available to the public. The Forest Service does this in several ways, including through a dedicated website, Treesearch (https://www.fs.usda.gov/treesearch/), which posts all the published scientific research conducted by R&D scientists.

6.3. Nature and Structure of Research Program

R&D is committed to impactful science, effective delivery, and organizational synergy, with a nimble and intentional approach to our work.

Research Priority Areas

- Applied science to support shared stewardship and improve forest conditions (e.g., market analyses, scenario planning, large landscape research, and decision support to further forest planning)

- Forest inventory and trend analysis (e.g., Forest Inventory and Analysis program, Resources Planning Act assessment, , iTree forestry tools, National Woodland Owner Survey)

- Enhancements to the wildland fire system, including prediction, planning, decision support, impact assessment, and recovery

- Wood product and market innovations

Research Framework

- Our research produces three key deliverables: resource inventory and assessment, decision support, and innovations in practices and utilization.

Foundational Research Areas

- Forest and grassland health

- Forest soils, air quality, and hydrology

- Silviculture and ecology (including forest ecology and fish and wildlife ecology)

Today, research is conducted by more than 400 scientists and several hundred technical and support staff located at 67 sites across the United States. This structure provides sites for long-term science and management studies of major vegetation types found across the United States, as well as diverse research areas operated in collaboration with partners. The FS R&D organization includes five research stations (Northern, Pacific Northwest, Pacific Southwest, Rocky Mountain, and Southern); the Forest

Products Laboratory; the International Institute of Tropical Forestry in Puerto Rico; and R&D Headquarters in Washington, DC. Although not in the research deputy area, there are also two

Technology and Development Centers operated by the National Forest System located in Missoula MT, and San Dimas, CA.

6.4. Role of the National R&D Office, Staff Directors, and National Program Leaders

The Washington Office of Research & Development serves the Forest Service and R&D-specific mission area, advancing and building support for the work of R&D and recognition of the public value that work creates. The national office focuses on strategic planning, policy development, oversight, and national coordination with other Forest Service mission areas as well as among research stations. The Washington Office of R&D also provides coordination and oversight of the entire R&D budget, working closely with the agency's national budget office on budget formulation, presentation, allocation to research stations, and performance reporting. Forest Service research is overseen by the Deputy Chief for R&D, with the assistance of the Associate Chief for R&D, and four Director-led staff areas. An important aspect of these staff areas is the development and representation of national research programs. Examples of national program activities include: leveraging research and research funding from other Federal agencies (typically in interagency working groups); coordinating with the R&D Deputy Chief's Office to report and promote R&D to Forest Service leadership and the Department, other agencies, and Congressional staff; fostering cross-station communication and collaboration among scientists; and developing working relationships with national-level non-profit organizations and professional and technical associations.

While National Program Leaders (NPLs) do not have budgetary or supervisory authority over Station programs and scientists, they coordinate national and Station elements of their research areas and, ideally, work with other NPLs and Station leadership and scientists to develop Station research priorities and programs that effectively address national issues as well as local and regional ones. In some cases,

NPLs make recommendations regarding the use of WO funds to coordinate research inputs among Station Scientists and to support grant programs in accordance with specific WO projects of national scope.

R&D Foundational Assets

Forest Service R&D maintains a vital network of 81 Experimental Forests and Ranges, 29 of which were established in the 1930s. Long-term records from some of these forests can provide unprecedented insights into global climate change, watershed function, disturbance recovery, and many other areas. Major research themes include, developing systems for management and restoration of forests, range lands, and watersheds; investigating forest and stream ecosystems; characterizing plant and animal communities; and observing and interpreting long-term environmental change.

Forest Service R&D also includes the Forest Inventory and Analysis (FIA) Program, which is considered a secondary unit of the Federal Statistical System. The United States has a highly decentralized statistical system, spanning 125 agencies spread across the Government, all of which are engaged, to some degree, in collecting data and producing statistics. The Office of Management and Budget's Statistical and Science Policy (SSP) Office, headed by the U.S. Chief Statistician, coordinates the activities of the Federal statistical system to ensure the efficiency and effectiveness of the system as well as the integrity, objectivity, impartiality, utility, and confidentiality of information collected for statistical purposes. The FIA program is legislated to provide the Nation's forest census, which includes forest conditions, landowner characteristics, and timber products output data. These data are

fundamental to the public and private sectors for policymaking and decisions about forest investments and are vital to researchers and scientists.

6.5. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)

The Forest Service utilizes many means of technology transfer and science delivery that include, but are not limited to, marketing efforts at tradeshows; marketing in cooperation with universities; patents; webinars; workshops; partnerships; field visits; coordination and participation in conservation education and citizen science; public outreach; and, most, critically publications.

Many metrics associated with these efforts are currently being tracked, and the Forest Service plans to track new metrics such as social media, web hits, and citation indexes.

The principal contact for technology transfer via intellectual property agreements, patents, and licensing within the Forest Service is the Technology Transfer Coordinator (TTC), who reports to the Washington Office (WO) and is located at the Washington Office and Baltimore field office. The Forest Service Patent Program receives and tracks all invention disclosures, providing guidance to scientists regarding all aspects of intellectual property protection. The Forest Service Patent Program is changing the emphasis from utility patent filing to provisional application filing and seeking a development partner and/or extensive marketing prior to a decision to file the utility patent. Reducing the technology to practice under a cooperative research and development agreement (CRADA) greatly increases the opportunity for successful development. The goal of this program is to file provisional patent

applications and involve the inventing scientist to help find a CRADA partner prior to filing a utility patent. This process includes working with the USDA Small Business Innovation Research (SBIR) program. The Patent Program conducts prior art searches and prepares all needed paperwork for the U.S. Patent and Trademark Office. The Patent Program also oversees contract law firms that draft utility patent applications (applications are filed by USDA Office of General Counsel), and files and prosecutes applications in the Patent Office. Draft patent licenses are prepared by the Forest Service Patent Program and signed by the Agricultural Research Service Office of Technology Transfer. Forest Service commercial licenses are royalty-based only with a priority toward making the technology available for internal Forest Service management use along with industry support.

CRADAs and other technology transfer agreements for the Forest Service are handled by the Forest Service Grants and Agreements Specialists in conjunction with the Forest Service TTC, with patent marketing responsibilities falling to the Forest Service Patent Program. If a partner or a successful market plan (this could involve procurement for Forest Service use) cannot be developed, the technology will be published and placed in the public domain.

The Forest Service Patent Program's goal is the broadest dissemination of scientific outcomes, and the Patent Program desires to support, not encumber or delay, such dissemination.

R&D will also continue to build a scientific foundation for natural resource management and policymaking at multiple spatial scales in forest and rangeland ecosystems. Methods used include conducting leading-edge research, synthesizing existing research, and improving access to and

highlighting field research to identify and prioritize critical management-driven needs. The data and research generated through this work are an important part of Forest Service technology transfer, and Forest Service R&D will continue to gather, analyze, provide, and report on data to improve management decisions. In addition to the FIA program mentioned above, FS also has "big data" residing in Star Metrics and VIVO, its fire weather modeling, its remote sensing and landscape analyses, and its tracking of weather and hydrology at the Experimental Forests and Ranges. Forest Service will also continue to add data collection points to its internal data collections programs, Research Information Tracking System (RITS) and iWEB, to allow better reporting, distribution, and management decisions.

Publications, agreements, patents, partnerships and data will continue to provide practical solutions to problems and issues by creating technologies, tools, methods, and information that serve the needs of internal customers with the National Forest System and State and Private Forestry, as well as other Federal agencies, universities and international communities.

6.6. FOREST PRODUCTS LABORATORY

The Forest Products Laboratory, based in Madison, Wisconsin, promotes healthy forests and forest-based economies through the efficient, sustainable use of our wood resources. The long-term health of our Nation's forests depends on sound conservation practices, including utilization. Since 1910, the Forest Products Laboratory (FPL) has used science and technology to conserve and extend our Nation's forest resources. Many everyday products and processes have been improved through FPL research, such as building products (structural and composite), housing, paper, bridges, adhesives, packaging,

recycling, biofuels, and wood preservatives, to name a few. Historically, FPL has contributed to great improvements in areas such as wood finishes, sawing and drying techniques, prefabricated housing, and lumber grading.

Forest Products Laboratory Research Priorities

- **Advanced Structures**: New technologies referred to as mass timber provides the means to engineer taller wood buildings and enable much faster assembly of multi-story buildings.

- **Nanotechnology:** Woody cell walls can be disassembled into fundamental nano-scale particles that have applications as varied as oil-well drilling fluids, barrier films, high-performance composites and improved cement.

- **Forest Biorefinery/Woody Biomass Utilization**: Particle boards, wood pulp, cellulose nanomaterials and biorefinery are commonly produced from smaller-diameter wood and, in some cases, slash and other wood wastes. Increasing the market for smaller-diameter trees will increase value sufficiently to pay all logging and transportation costs and increase the rate at which overgrown forests can be treated.

- **Advanced Composites**: New products, like wood-plastic composites, and potential products, like cellulose nanomaterial-reinforced composites, provide new lightweight materials for

- applications as varied as deck boards, lightweight vehicle parts, and lightweight armor.

Forest Products Laboratory 2020 Research Highlights

Guide for selection and use of pressure-treated wood

Wood is a versatile and sustainable building material but may be vulnerable to fungal decay and insect damage when used outdoors or otherwise subjected to moisture. Pressure treatment with wood preservatives is the most common method of protecting wood from this biological deterioration. However, users are sometimes uncertain about the type of treated wood to use, the properties of treated wood, and how to construct with treated wood. This publication summarizes characteristics of pressure-treating preservatives and provides guidance for selection of pressure-treated wood for specific applications. It also discusses construction practices, service life expectations, and environmental considerations. Drawings and examples are included for common treated wood construction projects such as decks, docks, and bridges. The intended audience for this publication is users of pressure-treated wood such as homeowners, builders, contractors, engineers, and architects.

Comparing juvenile wood depictions in the literature to wood property maps generated for mature longleaf pine trees

Juvenile wood in the southern pines is usually shown as a central core of wood surrounded by mature wood, the latter tapering down in thickness when moving from the base of a tree to its crown. This study

addresses the degree to which different juvenile wood depictions presented in the literature are applicable to a sampling of 70-year-old longleaf pine (*Pinus palustris* Mill.) trees.

Juvenile wood (corewood) has been widely studied given its high contribution to the wood resource, especially for usable timber obtained at short rotation ages. Reviews of juvenile wood in the literature provide insight into its physiological origin, anatomical features, chemical/physical/mechanical properties, and utilization. Several illustrations of juvenile wood in pines have been generated to explain the variability in the aforementioned properties in a typical pine tree stem. The present study addresses the degree to which different representations of juvenile wood are applicable to a sampling of 70-year-old longleaf pine (Pinus palustris Mill.) trees. Wood property maps were derived from X-ray densitometry data gathered from tree disks taken at every 61 cm along each tree bole. Altogether, the wood property maps and data comparisons suggest that the more complex illustrations of juvenile wood appear to align with the study trees, attributable, in part, to their maturity and near maximum attainable height.

Global and regional outlooks for planted forest area based on the quadratic relationships with per capita income

This study provides insight into the prospective planted forest area futures through the year 2100 in various countries, aggregated into major regions and the world, using the estimated quadratic relationships between per capita income and planted forest area, and compared with the past published projections based on a linear relationship.

The estimated planted forest model with the quadratic term projects increasing global planted forest area trends for the next three to four decades with declining trends thereafter. This outcome is consistent with the view that rising incomes are associated with progressively greater attention to the adverse environmental or social impacts of planted forests. For instance, depending on assumed socioeconomic futures, the projected gains in global planted forest area ranged from 9 percent to 14 percent by 2055, which were projected to decline thereafter, representing no increase to a 3-percent increase by 2100 compared to the 2015 level.

Global and regional forest area projections using an updated Environmental Kuznets Curve model

Forest resources are critical to environmental, economic, and social development. Therefore, understanding how global forest area will evolve in the future is important. This study used an updated Environmental Kuznets Curve (EKC) model to project total forest area through the year 2100 in 168 countries, using variables including income, rural population density, and the size of the labor force under different world visions of economic and demographic changes represented under the Shared Socioeconomic Pathways (SSPs).

This study updated the estimate of the EKC model of forest area using sets of panel data capturing historical and the most recent socioeconomic trends and use. It then uses the updated model to evaluate how total forest area in 168 countries would develop over the next 100 years under alternative assumptions of economic and demographic changes. The econometric analyses showed that aggregate

global forest area would increase by 7 percent in SSP3 (a future with the lowest rate of economic growth) to as much as 36 percent in SSP5 (a future with the highest rate of economic growth) by 2100 relative to 2015 levels. By evaluating the projected forest area trends globally and across major world regions, under alternative future scenarios of economic and demographic changes, this study gauges the usefulness of the estimated EKC model in providing a plausible projection of forest area that will be needed in future studies and/or policy simulations employed in global forest sector models.

Maleic acid hydrotropic wood fractionation at atmospheric pressure

This study developed a process using maleic acid, an FDA-approved indirect food additive (21CFR175-177), for sustainable fractionating lignocellulosic biomass at atmospheric pressure, which substantially facilitates the production of lignocellulosic nanofibrils (LCNFs) through mechanical fibrillation, sugars/biofuels through enzymatic hydrolysis, lignin aromatics from light color and minimal condensed lignin, and furans from hemicelluloses through catalysis.

The process uses maleic acid to fractionate lignocellulosic biomass into its three major components of lignin, hemicelluloses, and cellulose. Once separated, the components can be further processed into more valuable products. The process uses maleic acid at relatively low temperatures and is operated at atmospheric pressure, which would reduce equipment costs for commercial implementation. The maleic acid is recycled in the process, which is both economically and environmentally friendly.

After the biomass is treated with the maleic acid solution at ~ 100 °C for 30-60 minutes, the lignin and hemicelluloses are dissolved, leaving behind cellulose-rich solids. The lignin and cellulose are carboxylated by maleic acid which can be beneficial for further processing. Because maleic acid is a hydrotrope, it loses its solvent action on lignin when diluted below a certain concentration, or minimal hydrotropic concentration (~ 25 wt%). Therefore, the dissolved lignin is recovered simply by diluting with water through precipitation. The diluted solution can then be heated above boiling, which converts the remaining dissolved hemicellulose to furans, another valuable class of chemicals, while evaporating water for acid reuse.

As the process is carried out at low temperatures for a short period of time, the dissolved lignin is light in color, very similar to native lignin with low extent of condensation, which facilitated its catalytic conversion to monophenols, showing promise for producing platform aromatic compounds. Furthermore, lignin carboxylation facilitates its dispersion which aids its use in composite products and other applications.

The cellulose-rich solids can be mechanically processed into micro and nano-fibers with low energy inputs, due to the removal of lignin and hemicelluloses. Additionally, due to the added carboxylation of lignin and celluloses, a “lubrication effect” is provided. The cellulose-rich solids can also be easily enzymatically hydrolyzed into glucose for subsequent use in bio-ethanol or biochemical production using low doses of cellulase enzymes to save costs. The low dosage of enzymes is achieved because the carboxylation prevents the enzymes from attaching to lignin through electrostatic repulsion rather than cellulose.

Evaluating fire performance of adhesives used in CLT

This study is part of a research project examining fire risk in cross laminated timber (CLT) buildings. The research focuses on how adhesives used to hold wood composites together perform under fire to ensure strong, fire-safe construction.

"Delamination," a major concern for CLT fire safety, can occur when the adhesive bondline fails in the panel before it chars, which can lead to additional fuel for fire regrowth. Understanding the mechanical strength and stiffness of the adhesive bond under elevated temperature is one of the fundamental steps toward better understanding delamination. The current understanding of delamination is based on full-scale tests of CLT structures. We are developing small-scale tests that can be performed in a laboratory to cheaply screen adhesives and better understand fire risk with different adhesives.

Bonding performance of adhesive systems for cross-laminated timber treated with micronized copper azole type C

Expanding the use of cross-laminated timber (CLT) to outdoor applications is "one sticky problem." Research must examine compatibility between adhesive and wood preservative, evaluate bond strength and wood failure under applied forces, and test bond durability to withstand accelerated weathering without delamination.

Parameters for three adhesive systems (melamine formaldehyde, resorcinol formaldehyde, and one component polyurethane) were described for manufacturing 3-ply CLT from 35 mm thick boards that were untreated or treated with two retentions of the wood preservative MCA-C (micronized copper azole – type C). All adhesive and preservative retention combinations met the minimum standard requirements for wood failure percentage. The low preservative retention (1.0 kg/m3 for above ground use), however, reduced block shear strength regardless of adhesive, while the high retention (2.4 kg/m3 for ground contact use) did not affect block shear strength when the adhesive was resorcinol formaldehyde or polyurethane. In the accelerated weathering test, only the polyurethane resin provided satisfactory bonding performance for all treatment levels. These combined results indicate that under these test conditions, best bonding performance was obtained with the one-component polyurethane system.

Durable, cost-effective timber bridges

Timber bridge design advances support construction of cost-effective and durable timber bridges. This project supported the development of design aids to improve understanding of timber bridge materials, design, and durability details for contemporary timber bridges. In addition to design aids, the project resulted in the construction of two demonstration bridges highlighting its potential.

Measurement of moisture-dependent ion diffusion constants in wood cell walls

Diffusion constants of inorganic ions diffusing through individual wood cell wall layers were measured for the first time at moisture conditions below water saturation.

Renewable wood resources in our Nation's forests are poised to play a major role in the future bioeconomy, both as a feedstock for biorefineries producing energy, chemicals, and fuels, as well as continuing to be the basis for wood-based construction materials. However, achieving the full potential of wood resources is hindered by an incomplete understanding of many fundamental properties, including how chemicals are transported through wood cell walls. For example, diffusion constant measurements of inorganic ions moving through wood cell walls at moisture levels below water-saturation are completely lacking.

To provide this needed information, we developed synchrotron-based X-ray fluorescence microscopy (XFM) as an experimental tool to measure time-dependent concentration profiles of inorganic ions diffusing through individual loblolly pine (*Pinus taeda*) cell wall layers. Ions were locally applied using either KCl or CuCl2 aqueous salt solution microdroplets and experiments were performed under 70 percent, 75 percent, or 80 percent relative humidity (RH). An analytical model based on Fick's second law for diffusion was used to calculate diffusion constants.

Results revealed that diffusion rates increased with RH, the larger Cu2+ diffused more slowly than the K+, and the Cl- diffusion constant was the same as that for the counter cation, indicating cations and anions diffused together to maintain charge neutrality. This more complete, quantitative description of

diffusion in wood cell walls will enable optimization of cell wall diffusion processes for specific end uses and accelerate utilization of wood resources to meet our societal needs.

Role of leaf litter in above-ground wood decay

The effects of leaf litter accumulation are often a secondary consideration in above-ground wood construction but can have severe detrimental impacts if not properly managed. The goal of this research was to study the contributions of leaf litter accumulation to wood decay and to characterize the fungal communities in wood exposed to leaf litter versus unexposed. Wooden samples were evaluated over 41 months to compare severity of decay in blocks exposed to young and aged leaf litter compared to unexposed controls. Also, amplicon-based sequencing was performed to compare fungal communities at two time points within the study. Results showed that contact with leaf litter led to accelerated decay and higher average moisture contents. Contact with leaf litter also contributes a significant amount of decay fungal inoculum as evidenced by DNA sequencing of wood and surrounding leaf litter. The results of this study highlight the importance of leaf litter to fungal colonization and subsequent decay hazard for wood in above-ground exposure.

Investigating the role of moisture in durability of acetylated wood

Acetylated wood is the most common form of modified wood in the world and is gradually gaining acceptance in the United States as a form of wood protection. Acetylated wood is less prone to dimensional shrinkage and also exhibits increased resistance to fungal attack. The exact mechanisms of

fungal resistance are not fully understood but have been a focus of the bio-deterioration research community for several decades.

However, moisture exclusion has been studied extensively as a potential mechanism. Past research has indicated linear relationships between level of acetylation (expressed as weight percent gain or WPG), wood moisture content, and mass loss due to fungal decay. In a recent special issue of the journal *MDPI Forests*, an FPL laboratory study aimed at investigating the effects of moisture on brown rot fungal resistance of wood acetylated to various levels was presented. The goals of this study were to investigate if the observed reduction in decay of acetylated wood was solely due to the reduction in moisture content or if there are additional anti-fungal effects due to the modification.

An important finding of this study was the determination that fungi actively confound laboratory measurements of mass loss in acetylated wood because they accumulated biomass during the process and also produce water as part of their metabolic process. These observations will be used to inform and direct future studies aimed at identifying durability mechanisms of acetylated wood.

Improving the tools and practice for designing moisture-safe wood buildings

Architects and engineers face new challenges due to the changing climate, new engineered wood products, and the need to make buildings more energy efficient. Historically, we have been able to rely on years of experience to design safe and durable wood buildings.

However, the timber available from forests has changed, leading to innovations in engineered wood products. These products need to have their moisture properties characterized and accounted for in design. Similarly, the climate is changing, so we can no longer rely on older rules of thumb for design in a particular region. Design tools are needed to be able to assess the durability of wood buildings under these new conditions and the requirements for energy efficiency.

FPL researchers measured the moisture properties of cross-laminated timber (CLT), a newer mass timber panel, and validated that computer design tools provide realistic results for CLT. Further, we want buildings to be able to dry out when they get wet, so they remain safe and durable. FPL researchers have suggested new modeling methods which help predict drying. This is all part of the ongoing work to ensure design tools provide results that are useful for the next generation of safe and durable wood structures.

Seeing is believing: Finding the right enzyme for the job

One of the most expensive steps in converting forest biomass to chemicals is the cost of enzymes to convert cellulose into soluble cellobiose. In cooperation with University of British Columbia, National Renewable Energy Laboratory and Chalmers University in Sweden, FPL researchers used new microscopy techniques to make specific kinds of cellulose-degrading enzymes glow while they attack different parts of a wood fiber. One enzyme stuck mostly to fiber kinks, where the cellulose was disordered, and quickly degraded these zones, shortening the fibers and making them more flowable.

Another related enzyme stuck to the long, straight fiber sections. The finding allows better prediction of the cellulase mix needed for a specific biomass feedstock, reducing enzyme cost.

Simple and effective biobased water purification adsorbents for arsenic and industrial dye capture

A versatile contaminant absorbent was produced using strong affinity between nanomaterials extracted from wood and waste crab shells. The result is a promising new material for water purification, offering simple, effective, and green alternatives to synthetic adsorbents.

The rapid self-assembly of nanocellulose and nanochitin, was harnessed to produce high-efficiency and versatile biohybrid hydrogel (BHH) and aerogel (BHA) for water purification. The self-assembly process was driven by the electrostatic force between negatively charged TEMPO oxidized cellulose nanofiber (TOCNF) and positively charged partly deacetylated chitin nanofiber (PDChNF). The TOCNF were extracted from wood at the Forest Products Laboratory and the PDChNF were extracted from shrimp shells, a waste product. Self-assembly took place spontaneously at room temperature and without adding any crosslinking agents throughout the process. The assembled network results in the three-dimensional (3D) BHH that is physically cross-linked via both electrostatic interactions and hydrogen bonding between TOCNF and PDChNF. This network was freeze dried to obtain the BHA that exhibits a highly porous interconnected structure with a specific surface area of 54 m2/g. This structure is ideally suited for adsorption of toxic metalloid ions and organic pollutants due to the availability of its internal active sites.

Arsenic and methylene blue are common contaminants in drinking water and industrial run off, respectively, and their removal is highly desired. This research showed that the BHA displayed super-high adsorption capacities of 217 mg/g for As(III) under neutral pH conditions and 531 mg/g for methylene blue (MB) under an alkaline aqueous condition with rapid adsorption kinetics, in sharp contrast to conventional biobased adsorbents. Additionally, the BHA is reusable as acidic conditions cause the desorption of the absorbed contaminates. The regenerated BHA exhibited high MB adsorption capacity of 505 mg·g−1 even after five successive adsorption−desorption cycles. This versatile BHA produced via a facile preparation strategy is proven to be a promising renewable adsorbent for water purification, offering simple, effective, and green alternatives to the conventional adsorbent from synthetic polymers.

Flexible magnetostrictive nanocellulose composites for actuation, sensing, and energy- harvesting applications

Cellulose nanofibril films embedded with magnetostrictive particles were shown to predictably bend under a magnetic field and to change their magnetic properties under stress, making these composites potential candidates as actuators, sensors, and energy-harvesting applications.

Researchers at the Forest Products Laboratory and University of Wisconsin-Milwaukee created composites consisting of cellulose nanofibrils and Terfenol-D magnetostrictive particles. Various constructs of the materials were created, including laminating multiple layers with and without magnetostrictive particles. Magnetostrictive particles were also oriented in various configurations during

fabrication. The effects of laminates and particle orientation on the magnetostrictive (in which a magnetic field creates shape changes) and Villari (change in magnetic properties due to stress) were examined. Composites containing particles with in-plane alignment had the greatest sensitivity to magnetic field for actuation but the lowest performance for stress sensing or energy harvesting applications. Composites with additional CNF layers exhibit markedly improved sensitivity in Villari experiments.

Rapid production of high- strength and translucent cellulose nanofibril sheets

Conventional single-screw extrusion was used for continuous processing of mechanically fibrillated cellulose nanofibrils (CNFs) into wet sheets. A high shear mixing procedure was used to preprocess highly loaded CNF pastes with a processing aid like carboxymethyl cellulose (CMC), xanthan gum (XG), or anionic polyacrylamide (aPAM). The higher solid loadings significantly reduced the preparation and drying time. The water-retention ability and stability of CNF suspensions containing different processing aids were assessed through centrifugation and zeta potential analysis. Extrusion of the prepared pastes showed that cohesive sheets could be produced continuously at output rates of 7.45 ± 0.47 kg/h (or 1.14 ± 0.072 dry) without the introduction of surface defects. Rheological analysis linked extrudate homogeneity and reduced defects to a stronger Newtonian response for CNF/CMC pastes when compared to pure CNFs. However, CNF/XG and CNF/aPAM pastes exhibited a significant shear thinning response. This coincided with more frequent appearance of observable aggregates and defects in the films. Tensile testing of the pressed and heated CNF/CMC extrudates revealed equivalent mechanical properties to cast CNF films prepared through conventional slow solution casting.

Calendering of wet CNF/CMC extrudates showed that full consolidation can be achieved, thus providing a way to continuously dry and press the wet films.

Gene conservation among lignocellulose-degrading fungi

Certain wood decay fungi have evolved the capacity to efficiently degrade all the major components of cell walls, including cellulose and the recalcitrant polymer, lignin. These microbes play a key role in forest carbon cycles, and their unique enzymes have attracted considerable attention for the bioconversion of woody biomass to useful chemicals. Nevertheless, considerable uncertainty remains regarding the uniformity of the enzymatic mechanism particularly in light of the well-known geographic and climatic diversity between species.

Addressing this question, scientists sequenced the genomes of *Pycnoporus cinnabarinus*, *P. coccineus* and *P. sanguineus* and compared their gene content, transcriptomes and extracellular proteins. The genetic repertoires were strongly conserved irrespective of geographic and climatic origins, and a core set of degradative enzymes were identified. Co-occurrence of extracellular H2O2-generating enzymes with H2O2-consuming enzymes were observed in the three species, although certain transcript pairs were independently regulated. The data also suggested synergism between cellobiose dehydrogenase-coding genes and at least one lytic polysaccharide monooxygenase gene. This study highlights a conserved core of fungal enzymes underlying mechanisms of lignocellulose degradation.

Life-cycle assessment of redwood lumber products in the United States

Global demand for renewable and sustainable materials such as wood products is growing. To support growth, a scientific approach is necessary to illustrate the environmental benefits of wood products. This report provides a detailed cradle-to-gate life-cycle assessment (LCA) and update to the environmental impacts associated with redwood (*Sequoia sempervirens*) lumber production in the United States. The results illustrated that redwood lumber production has a very low carbon footprint (37.97 kg CO_2e/m^3 of lumber) and stores carbon about more than 18 times compared with its cradle-to-gate carbon footprint.

FPL's field-portable XyloTron outperforms laboratory-based DART mass spectrometry identification of woods in the mahogany family

Imagine you are inspecting a wood shipment and you suspect someone is smuggling mahogany, an endangered species. You could remove a small specimen, ship it to a distant laboratory, and wait days for an answer, or you could use FPL's XyloTron to capture an image of the wood's anatomy and get an answer in about two seconds. Instead of selecting only one or two boards to test in the laboratory, you could choose to test dozens of boards, and decide whether to detain the shipment.

Many wood identification technologies have been developed or improved in recent years, including attempts to compare results between technologies. The utility of such comparisons is greatly reduced when the species tested with each technology are different and when performance metrics are not calculated or presented in the same way. FPL's XyloTron was used to develop a species-level computer vision model and was presented along with a side-by-side comparison for species- and genus-level identification of the 10 species of *Meliaceae* studied by other workers using DART mass spectrometry.

The species-level accuracies of the XyloTron and the DART mass spectrometry models are comparable. However, the genus-level accuracy of the XyloTron model is higher than that of the DART mass spectrometry model. Given that not all wood identification problems are species-level problems, genus-level prediction metrics can be important for real-world adoption of a technology.

Each XyloTron unit costs less than $2000, requires minimal user expertise to operate, is designed to be operated in the field, and, after initial acquisition, requires only electricity (e.g., the battery power of the laptop, for field use). A mass spectrometer, by comparison, is restricted to a single indoor location, costs approximately $250,000, and requires an operator with specialized expertise to develop an identification result.

Approval of cross laminated timber shear wall system in U.S. codes

Cross laminated timber (CLT) is an innovative mass timber product that has now been commonly accepted as a new-generation engineered wood product with great potential to expand the wood building market. With the introduction of CLT to the U.S. construction market and the current modern urbanization trend, many believe that it can serve as a very effective solution for commercial and mixed-use building markets in seismic regions. The purpose of this study was to facilitate recognition of CLT seismic system in the U.S. building codes for the first time in 50 years.

CLT offers many advantages such as the potential for mass production, prefabrication, speed of construction, and sustainability as an environmentally friendly and renewable construction product.

Good thermal insulation, acoustic performance, and fire ratings are some additional benefits of the system. Despite these advantages, the lack of a current design approach is one of the challenges inhibiting widespread adoption of CLT in North America.

One area that requires attention is the development of seismic performance factors for CLT lateral systems so designers in the United States can begin to utilize CLT shear walls in seismic regions. CLT-based Seismic Force Resisting Systems (SFRS) are not recognized in current U.S. design codes. The study follows a systematic approach that integrates design method, experimental results, nonlinear static and dynamic analyses, and incorporates uncertainties. The research consists of various development phases that encompass archetypes, design methodology, component and system testing, nonlinear structural modeling, and incremental time history analyses. All phases of development resulted in both the structural design procedure and associated seismic design parameters for the first approved wood-based lateral force resisting system in over 50 years.

The design procedure and seismic design parameters were approved by the Building Seismic Safety Council of the National Institute of Building Sciences in the spring of 2020. While the CLT shear wall design procedure was approved in July 2020 for the next version of the Special Design Provisions for Wind and Seismic, approval of the seismic design parameters for inclusion in the next version of ASCE 7 Minimum Design Loads and Associated Criteria for Buildings is ongoing. This final approval will result in the CLT shear wall lateral restrain systems to be in all U.S. building codes (such as the International Building Code). It will also eliminate the highest priority structural need as identified on the first Mass Timber needs assessment.

Evidence that the Ilopango volcano was the source of the colossal eruption of 539/40 CE

The Ilopango volcano eruption during the Maya Classic Period caused abandonment of an area of 20,000 square kilometers of a densely populated area of the southern Maya realm. Evidence of the age, magnitude, and sulfur release of the eruption establish it as one of the volcanic causes with a profound impact on climate and society between 536 and 550 CE. The chronology is based on measurements within subfossil tree trunks enveloped in pyroclastic deposits.

6.7. Forest Service Decision Support Tools and Data

A decision support tool (decision support system (DSS)) is a computer-based information system that supports business or organizational decision-making activities. Decision support tools serve the management, operations, and planning levels of an organization (usually mid and higher management) and help people make decisions about problems that may be rapidly changing and not easily specified in advance—i.e., unstructured and semi-structured decision problems. Decision support systems can be either fully computerized, human-powered, or a combination of both.

All aspects of forest management, from log transportation and harvest scheduling to sustainability and ecosystem protection, have been addressed by modern decision support tools. In this context, the consideration of single or multiple management objectives related to the provision of goods and services with tradeoffs that need to be factored into decisionmaking. The Forest Service's Community of Practice

of Forest Management Decision Support Systems (http://www.forestdss.org/) provides a large repository of knowledge about the construction and use of forest Decision Support Systems.

The Forest Service currently reports 69 decision support tools. Some examples are:

- T9ree) - T is a forest simulator developed from biological as well as economic submodels for individual trees. T is designed to simulate alternative treatment schedules for all compartments in a planning area.

- LANDIS Landscape Disturbance and Succession model - LANDIS is designed to model forest succession, disturbance (including fire, wind, harvesting, insects, global change), and seed dispersal across large (>1 million ha) landscapes.

- RODPOST - RODPOST is applied for optimizing the assortment distribution of single trees, based on information about the length and diameter of the log.

- Invasive Plants in Southern Forests App - This app provides information on accurate identification of the 56 nonnative plants and groups that are currently invading the forests of the 13 Southern States. Recommendations for prevention and control of these species are provided.

- FMPP - The Forest Management Planning Package is an existing planning system used in practical forestry in Sweden. It focuses on the economically effective resource management of

forest timber. The FMPP integrates economic theory, objective inventory measurements, growth forecasts and optimization methods. It is essentially aimed at long-term (strategic) planning of larger forest holdings. The planning problem can be formulated and solved in two ways: (1) A non-linear objective function and mathematical optimization result in a compromise between maximization of economics benefits (Net Present Value) and a sustainable development (sustained net-revenue profile); and (2) A linear programming package, JLP, is utilized to maximize Net Present Value under some preselected restrictions.

- EMDS - The system provides decision support for landscape-level analyses through logic and decision engines integrated with the ArcGIS geographic information system. The NetWeaver logic engine evaluates landscape data against a formal logic specification designed in the NetWeaver Developer system, to derive logic-based interpretations of ecosystem conditions. The decision engine evaluates NetWeaver outcomes, and data related to the feasibility and efficacy of land management actions, against a decision model for prioritizing landscape features built with its development system, Criterium DecisionPlus (CDP). CDP models implement the analytical hierarchy process, the simple multi-attribute rating technique, or a combination of the two methods. The system has been used in a high variety of applications.

- Agflor - This tool helps access the impacts of policy changes on regional land use patterns. It was used by Portuguese Ministry of Agriculture Regional Office of Alentejo (DRAPAL) to assess the impacts of common agricultural policy changes on agricultural and forestry activities on regional land use patterns over an area extending over 2 million hectares.

- Forest Vegetation Simulator (FVS) - Forest Vegetation Simulator (FVS) is a family of forest growth simulation models.

- Fuel Characteristic Classification System, Version 3.0 - The system predicts surface fire behavior including reaction intensity, flame length, and rate of spread; and surface fire behavior, crown fire, and available fuel potential using a 9-point index.

- The Hot-Dry-Windy Index improves fire weather forecasting - A new tool helps fire managers anticipate when wildfires could become erratic or dangerous.

Data – Forest Service Research Data Archive (FSRDA)

FSRDA was created in 2010 to publish and preserve digital scientific data collected from studies funded by FS Research and Development (FS R&D) and the interagency Aldo Leopold Wilderness Research Institute (ALWRI). In 2012, our scope expanded to the interagency Joint Fire Science Program (JFSP). To date, ~30% of our publications are from JFSP-funded studies. In 2019, we started a pilot project to provide publishing support for USDA APHIS' National Wildlife Research Center. FSRDA actively

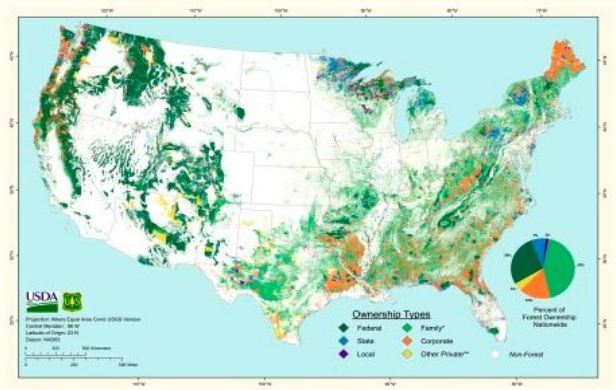
works with the network of FS experimental forests, ranges, and watersheds (EFRs) to publish and preserve the highly valuable data from their long-term studies. This work frequently involves converting paper-based historical data into modern digital formats and assembling metadata on the data from study notes, interim reports, and scientific articles.

FSRDA released 85 new data publications in FY 2020. Data publication downloads increased 28 percent relative to FY 2019. This is the ninth straight year of substantive increases in our customer base. Interest in western wildfires was reflected in strong interest in FSRDA data publications describing wildfire occurrence and wildfire hazard potential. This interest appeared as downloads and use of these publications on third-party websites that presented value-added content.

FSRDA staff help to coordinate the availability of Forest Service R&D-created datasets to National Forest System users via the FS Enterprise Data Warehouse (EDW). The FSRDA staff also have Google Analytics information on where FS customers come from and, based on user data, publications are being used by the private sector for determining insurance premiums (fire occurrence dataset), by higher education as part of data science training, and by various State and local governments. (For example, the State of New Mexico's web site presents fire data from one of the FS publications.) They also provide digital support for some of the agency's most popular articles (the most-downloaded article from Treesearch is a compilation of timber statistics); FSRDA staff published a companion publication that puts the table information in Excel format for easier analysis and re-use. It's not the most popular publication – that would be the fire occurrence dataset – but it will be in the top 10 when all usage is analyzed.

FSRDA staff have a leadership role on the team guiding the Forest Service transition to the ISO geospatial metadata standard. This supports FS compliance with a USDA departmental directive and with the Geospatial Data Act of 2018.

6.8. Who Owns the Forest?



U.S. forest ownership map. Jake Hewes, USDA Forest Service

Contrary to popular belief, nearly two-thirds of forests in the conterminous U.S. are privately, not publicly, owned. The distribution of ownership is 43 percent family, 28 percent Federal, 16 percent corporate, 7 percent State, and 4 percent other private land (which includes Native American Tribal ownerships). By showing the distribution of forest ownership, the *Forest Ownership Map of the Conterminous United States*, developed by the Northern Research Station, promotes the development of policies that support the conservation and wise management of public and private forests.

6.9. State & Private Forestry

Encompassing two-thirds of America's forests, State- and privately-owned lands provide public benefits such as clean air, clean water, wildlife habitat, outdoor recreation, and most of the Nation's wood supply. These forests face many threats, including wildland fire, invasive species, pests and disease, and the permanent loss of working forest land to non-forest uses. The Forest Service State & Private Forestry (S&PF) division helps ensure that forest landowners have the best technical, educational, and

financial assistance available to achieve their unique objectives and to keep forests working for all of us. Below are just a few examples of S&PF Technology Transfer projects carried out in FY 2019

Tribal Relations

The Tribal Connections Viewer (https://www.arcgis.com/home/item.html?id=91a950377c264b7e84415ef2e91c3a49) is a new geographic information systems tool available to Forest Service staff, Tribes, and others that provides a visual, interactive map identifying Forest Service-administered/owned land, Tribal lands, and ceded lands all in one place. Nearly 4,000 miles of shared boundaries between Tribal lands and Forest Service-administered/owned land are identified. Like never before, Tribes and the Forest Service can now engage in shared land management activities across administrative boundaries and at larger landscape scales.

The Tribal Connections Viewer improves data-based decision making on incidents and in resource management for both tribes and the agency; encourages meaningful consultation and collaboration with our Tribal partners; shares technology and knowledge across boundaries and borders; honors treaty rights and the Federal trust responsibility; and identifies opportunities for new and expanded partnerships between Tribes and the agency or collaboration on conservation projects and programs, using the best data available.

The Tribal Connections Viewer uses the most current data available from the U.S. Census Bureau, Forest Service, Smithsonian Institution, and other sources to provide current and historical details, such as historic treaties, for each location on the map. Having this information easily available in one online resource will improve the efficiency of agency-Tribal coordination, collaboration, and consultation. The online resource helps to promote sound management of protected areas through conservation efforts, capacity-building activities, and education initiatives. It does so through the creation of an interactive mapping tool that shows where and how lands managed by the Forest Service connect or overlap with current Tribal trust lands. The accuracy of the tool is being continuously refined through input provided by users from Tribal nations, who will note where corrections should be made, in comparison with their own local data.

Wildland Fire

Wildfire season is year round and, regardless of where they start, wildfires impact thousands of wildland-urban interface communities. Helping communities in fire-prone areas prepare for wildfire reduces impact on those communities, has the potential to reduce suppression needs, and helps protect civilian and firefighter lives. Addressing the impacts of wildfire on communities is an “all lands/all hands” effort.

Community Fire Adaptation: Federal, State, and local governments partner with non-profits, fire departments, and other stakeholders to reduce wildfire risk locally through the use of mitigation best practices. The Forest Service has developed best practices to enable effective, efficient, and sustainable

mitigation efforts locally. Those best practices are based on the best-available science, proven by experience on the ground, and shared with communities and partners nationwide.

Wildland-Urban Interface Research: The community wildfire risk reduction work the Forest Service and our partners share is based on science and verified by experience. Partners like the Joint Fire Science Program, the Insurance Institute for Business and Home Safety, the various Forest Service Research Stations, and Forest Service fire researchers form the foundation of best practices. As an example, the Forest Service, States, and partners have long thought messaging through public service advertising, literature distribution, and social media was the route to mitigation actions on the ground. Research supported by experience has shown that it is not the case. Messaging may help people become aware of their wildfire risk, but it is not a key factor in spurring them to take action to reduce risk. That takes one-on-one, face-to-face engagement at the local level and building trusted relationships. Sharing that information in an effort to change our approach to community wildfire mitigation is key to accomplishing risk reduction on the ground.

The Community Mitigation Assistance Team (CMAT) concept was piloted in 2015 and is now a standing resource for communities impacted by wildfire. The teams use the teachable moment of smoke in the air, high fire activity, or high fire risk to work collaboratively with community leaders to share best mitigation practices, help form local mitigation partnerships or coalitions, and plan effective and efficient mitigation programs that can live on in the community long after a wildfire or the deployment of the CMAT. The CMAT has worked with communities and helped mitigation coalitions in association with the Bridger-Teton National Forest, Rogue River-Siskiyou National Forest, Pisgah National Forest,

Pike and San Isabel National Forests, and the Okanogan-Wenatchee National Forest. The CMAT has also developed a stand-alone Community Mitigation Academy best mitigation practices course that is available to States or regions at no cost to share the most effective ways to reduce community wildfire risk and to build a local cadre to accomplish on-the-ground mitigation. See http://nrfirescience.org/resource/13555.

Working with Partners: Internal and external partners are key to getting work done in communities and to sharing the latest effective methods to accomplish risk reduction. An important long-term partner has been the National Association of State Foresters. In addition, we continue to increase technology transfer through important partnerships with career and volunteer fire departments nationwide. Work with the National Volunteer Fire Council helps share best practices for assessing homes and communities for wildfire risk and ways to share that information with residents: https://www.nvfc.org/programs/wildland-fire-asssement-program/. Another important partner, the International Association of Fire Chiefs (IAFC) supports the Ready, Set, Go! Program which focuses on readiness and situational awareness for safe and timely evacuation: http://www.wildlandfirersg.org. IAFC also supports the pilot Fire Department Exchange (FDX), which allows fire departments to share information about mitigation lessons learned and help one another improve on-the-ground wildfire risk reduction.

The FAC Learning Network, out of which grew the Fire Department Exchange, is a collaborative effort with the Forest Service, The Nature Conservancy and The Watershed Center. The FAC Learning Network's mission is to connect and support people and communities who are striving to live more

safely with wildfire. The Network is a catalyst for spreading best practices and innovations in fire adaptation concepts nationwide. The purpose of FAC Net is to exchange information, collaborate to enhance the practice of fire adaptation, and work together and at multiple scales to help communities before, during, and after wildfires: https://fireadaptednetwork.org/.

The Fire Adapted Communities Coalition was formed in 2009 and still functions primarily as a technology transfer information sharing effort between and among partners (and their individual audiences) engaged in community wildfire mitigation efforts (community fire adaptation). Coalition partners share the work they are doing to help communities reduce risk and their successes and work to collaborate for effectiveness and innovation across programs. Coalition members use webinars (recorded for later access), social media, videos, face-to-face learning sessions (also recorded), and workshops to share best practices. FAC Coalition members are the USDA. Forest Service, the National Association of State Foresters, the National Volunteer Fire Council, the Nature Conservancy, The Watershed Center, the Insurance Institute for Business and Home Safety, the National Fire Protection Association, Federal Emergency Management Agency (FEMA), U.S. Fire Administration, Department of the Interior bureaus, and the International Association of Fire Chiefs.

Forest Health Protection

The Forest Health Protection (FHP) Program provides technical assistance on forest health-related matters, particularly those related to disturbance agents such as native and non-native insects, pathogens, and invasive plants. FHP conducts aerial surveys, remote sensing, and aerial applications to assist

Federal and State partners and the public and to guide forest management actions to improve forest health. This effort makes scientific data available to land managers and States that can reduce the risk and impact of infestations. We work through partnerships across all lands, providing forest insect, disease, and invasive plant survey and monitoring information, and technical and financial assistance to prevent, suppress, and control outbreaks threatening millions of forested acres across the Nation. Our monitoring program is designed to determine the status, changes, and trends in indicators of forest condition on an annual basis, providing data to guide land managers in maintaining, enhancing, and restoring healthy forest conditions. The FHP program uses data from ground plots and surveys, aerial surveys, and other biotic and abiotic data sources and develops analytical approaches to address forest health issues that affect the sustainability of forest ecosystems.

FHP recently completed a 2018 update of the National Insect and Disease Risk Map (NIDRM) and has facilitated transfer of these digital data to the States in support of the 2020 State Forest Action Plan updates. The NIDRM provides a nationwide strategic assessment of the risk (hazard of tree mortality) due to insects and diseases. Values “At Risk” in the NIDRM represent the expectation that, without remediation, 25 percent or more of the standing live tree basal area will die over a 15-year (2013 to 2027) time frame due to insects and diseases. The 2018 update depicts areas where recent significant tree mortality events have occurred, removing these areas from “At Risk” conditions. Since 2012, upon completion of the last NIDRM, major tree mortality events from forest pest outbreaks, fire, and broad-scale forest harvesting operations have reduced or, in some cases, eliminated risk. A major tree mortality event was defined as one or more of the following:

- Areas depicted as forest cover loss in the University of Maryland Global Forest Change dataset.

- Three or more years of mortality mapped in aerial detection surveys (ADS).

- In the Eastern United States. only, 3 or more consecutive years of defoliation mapped in ADS.

The 2018 update does not account for increases in risk due to recent tree growth and density, which can make additional trees susceptible and vulnerable to new forest pest attacks.

NIDRM provides the following in support of State Forest Action Plans:

- A spatially explicit dataset of areas at risk for experiencing 25 percent or more tree mortality from insects and diseases through 2027.

- A critical portion of the timetable of forest health, by linking historical ADS data to future projections of forest pest mortality events.

- A baseline for monitoring the current and potential extent of new and existing forest insect and disease threats.

- Early identification of areas with potential for new forest health threats to help prioritize management activities and increase the affordability and effectiveness of control strategies.

- Improved communications and awareness of forest health threats.

Urban & Community Forestry

The Forest Service has a long history—well over three decades--of delivering urban forestry research, technology, and information to our partners, stakeholders, and customers. In FY 2019, the Urban & Community Forestry Program provided technical or financial assistance to more than 7,755 communities across the United States. Sharing agency knowledge and tools is essential to improving the management and long-term sustainability of urban ecosystems. Our partners and customers, including 63 State and territory forestry agencies, more than 35 national partners, more than 150 community tree groups, private industry, academic institutions, and municipalities, are asking the agency to continue providing much-needed science and technology delivery services. This demand is increasing as our audience and customer base expands to new user groups such as public works, planning, sustainability, and public health and safety professionals. The demand is also evolving as we aim to be more effective in reaching a diverse audience in communities of all sizes, and as information sharing becomes more essential. To best serve our customers, the FS formed the Urban & Community Forestry Technology and Science Delivery (TSD) Team in 2014. This team is made up of S&PF Urban & Community Forestry program managers and FS Research & Development personnel from around the country. The group's focus is on ensuring our urban forestry staffs are strategic, skillful, creative, and nimble in our science delivery efforts. The team employs a contemporary technology transfer approach in order to reach our diverse audiences, and to coordinate across deputy areas, regions and stations to ensure that we are sharing information that is timely, relevant, and easy to access, understand, and use.

For example, through a grant from the Urban & Community Forestry Program, the team partnered with American Forests and the National Association of Regional Councils to launch the Vibrant Cities Lab web platform to help policymakers, municipal executives, and urban forestry practitioners make science-based decisions about the trees that make their community healthier and more livable. Hosting more than 25,000 users to date, this platform provides curated summaries of the best available science in urban forestry and a toolkit and self-assessment that guides users as they work to improve urban forest plans and practices. In FY 2019, Lab advancements under development included a resilience section adapting Forest Service publications on storm readiness and response; a community-centered tool for prioritizing the most important urban forestry investments; and a funding finder tool on the website to help secure funding for urban forestry projects. Upcoming advancements include a toolkit to identify the complex barriers low-income people of color face in entering and sustaining careers in the tree care industry, as well as provide proven or innovative solutions. Adapting this publication into an online action guide on Vibrant Cities Lab will transform the site from a passive resource of information about jobs into a dynamic, interactive tool to help address some of the most pressing issues faced by disenfranchised populations and an industry seeking to fill a labor shortage.

Wood Innovations in Building

Wood may be one of the world's oldest building materials, but it is also now one of the most advanced, and the Forest Service is playing a critical role in providing assistance to State, Tribal, local, and private entities on how to incorporate wood as a green building material. By building stronger markets for innovative new wood products, we are supporting sustainable forest management, helping to reduce

greenhouse gas emissions, and putting rural America at the forefront of an emerging industry. One key avenue for providing technical assistance around the use of wood in building is through our partnership with WoodWorks. WoodWorks, an initiative of the Wood Products Council, provides free, one-on-one technical support to architects and engineers on wood building design. Through partnerships with the Forest Service, major North American wood associations, and other organizations, WoodWorks promotes the construction of wood buildings. The $2 million contributed by FS in 2017 leveraged an additional $4.5 million from the wood industry and Canadian government, allowing significantly greater impact than could have been achieved independently. WoodWorks provides technical expertise on a wide range of building types, including schools, mid-rise/multi-family, commercial, corporate, franchise, retail, public, institutional, and more. WoodWorks hosts yearly conferences across the country and provides workshops and training opportunities on a range of topics to expose architects and engineers to wood design. In FY 2017, WoodWorks directly or indirectly influenced the use of wood in over 500 buildings.

Owner Assistance

The FS cooperates with researchers and partners to understand landowner behavior and develop technical assistance programs that meet the interests and management needs of America's non-industrial private forest landowners. Through investments in the National Woodland Owners Survey, the Reforestation Nurseries and Genetic Resources program (RNGR), National Seed Lab, and the National Agroforestry Center, State & Private Forestry advances technology transfer. RNGR, a unique and innovative collaboration across deputy areas, provides science-based technical expertise to 1,400 native

plant nurseries. RNGR helps plant professionals respond to ever-increasing demand for high-quality, ecologically appropriate plant materials to address climate change, invasive species and pests, habitat loss, and post-wildfire restoration. In addition, RNGR employs contemporary technical transfer approaches to reach diverse audiences including Federal, State, private, Tribal, and international professionals through webinars, Native Plant Propagation Protocol database, *Tree Planters' Notes* (international applied journal focused on plant production and establishment), and website with over 70,000 downloads annually of articles pertaining to reforestation, restoration, and native plant production.

Forest Legacy (FLP), Community Forests and Open Space (CFP), Landscape Scale Restoration, and Forest Stewardship (FSP) programs ensure information sharing on forest management and conservation is timely, relevant, and easy to access and use for partners, including Federal, State, and local agencies, Tribes, non-profit organizations, and university extension programs. The Forest Legacy program has online implementation tools and is developing a resource library for States and other partners. FLP also supports the Land Trust Alliance's Learning Center that provides critical permanent forest land conservation information through online resources, webinars, and courses to over 900 land trust organization members.

In FY 2019, FSP, through State forestry agencies, provided technical assistance to over 602,000 private forest landowners. Through a partnership with the Forest Service, Yale University's Tools for Engaging Landowners Effectively (TELE) helps Federal, State, and local agencies, university extension, and non-profit organization staff to address complex conservation challenges using targeted marketing tools and

techniques. Hosting more than 50 workshops in 39 States and Guam, TELE has trained more than 1,500 people representing over 500 organizations and leading to 15,000 landowners taking action on more than 730,000 forested acres. In FY 2019, TELE developed online tools for natural resource professionals to foster peer-to-peer learning and streamline implementation of the TELE approach. Tools include marketing tips, lessons learned, a facilitator's guide, and a landowner engagement guide, a complete resource to designing landowner programs and communications.

Conservation Education

Forest Service Conservation Education (CE) helps people of all ages understand and appreciate our country's natural resources and learn how to conserve those resources for future generations. Through structured educational experiences and activities targeted to varying age groups and populations, conservation education enables people to realize how natural resources and ecosystems affect each other and how resources can be used wisely. Through conservation education, people develop the critical thinking skills they need to understand the complexities of ecological problems. Conservation Education also encourages people to act on their own to conserve natural resources and use them in a responsible manner by making informed resource decisions. FS Conservation Education is part of the advisory board of the CE-Works project, developed by the North American Association for Environmental Education and Stanford University, and designed to demonstrate the impact and value of environmental education by substantiating powerful anecdotes from across the field with empirical evidence. The project is conducting comprehensive literature reviews that demonstrate the impact of environmental

education on key environmental and social outcomes and is translating findings into communication tools to benefit the field.

For more than a decade, Conservation Education has partnered with Prince William Network to bring nature learning to classrooms through technology, including webcasts and webinars, and hosting online education materials. Under the FSNatureLIVE banner are numerous "LIVE" projects, each arranged around a theme and housed in a dedicated website, complete with broadcast links, associated curriculum and classroom grant opportunities. Recent projects include FreshWaterLIVE, WetlandsLIVE, and GrasslandsLIVE.

The Latino Legacy Youth Leadership in Nature Challenge and Green Ambassador model is an outdoor leadership training program that hosts approximately 20-25 diverse youth per session. The program serves first- and second-generation students of diverse ethnic backgrounds. This week-long connection with nature and natural resource career opportunities has provided visits and one-on-one networking with major Hispanic Serving Institutions, State universities, agricultural colleges, and governmental agencies.

The Natural Inquirer publications focus upon science, technology, engineering, and math (STEM) education, targeting 5^{th}-8^{th} grade students. Hardcopy and digital publications are available to students and educators. These publications educate students about research generated by the FS, engage youth in STEM education, and inspire youth to pursue science-driven careers. Scientist cards present information

on specific FS scientists from many different backgrounds, and many of the cards, which inspire young conservation leaders in the pursuit of natural resource-related careers, are translated into Spanish.

Partnering with the National Environmental Education Foundation, the FS reaches underserved children and their families through health care providers with prescriptions to recreate in parks and forests near their homes with an emphasis on underserved areas of the country. Over 880 health care providers have been trained about the health benefits of nature and have written over 1,000 Prescriptions for Outdoor Activity. They have also created digital applications for outdoor activity to help motivate technology-bound children to get outside.

7.0. WATER

National forests are the most important source of water in the United States. The annual value of water flowing from agency lands has been estimated to be $7.2 billion. More than 60 million Americans—including residents of cities such as Atlanta, GA; Denver, CO; and Portland, OR—rely on drinking water that originates on national forests. In a sense, the Forest Service is the Nation's largest water company.

Forests provide people with clean, reliable drinking water. But these waters are at risk due to the needs of growing human populations, continued conversion of forests to other land uses, and anticipated changes in climate conditions. Given such threats, it is important to understand how much drinking

water originates in forests, which populations and communities are served, and how best to regulate water quality through proper watershed management.

- A Rocky Mountain Research Station study published in 2015 showed that forests yield 46 percent of the mean annual water supply but occupy only 26 percent of the land area of the contiguous United States.

- A 2014 report published by the Southern Research Station showed that clean water begins in national forests for over 19 million people in the South—roughly the population of Florida. The report provides information at a level not previously available on the amount of surface drinking water provided by national forest lands to communities in the South. This information can help support partnerships among State, Federal, and nongovernmental organizations that work to conserve the forest cover that provides the area's clean, dependable water supplies.

How Forests Provide Clean Water

Small headwater streams determine the water quality of the larger rivers, lakes, and reservoirs that they flow into. Researchers used data from Hubbard Brook Experimental Forest to study the pathways water takes from the time it lands as rain until it reaches a headwater. By tracing water isotopes, they found that the median time it takes rain water to reach a stream ranges from 50 days during wet periods to 190 days during dry periods. The team took it one step further and measured changes in the concentrations of dissolved substances that naturally occur in water, such as calcium, and are often what make water

"hard" or "soft." They found that not only does the amount of time water spends flowing through forest soils determine how much a forest filters the water and removes dissolved substances, thereby impacting water quality, but also what path the water takes through the ground. Research like this could potentially help land managers target specific areas of a forest that provide the most filtration services for restoration or conservation to improve a forest's water filtering capabilities.

Best Management Practices Improve Water Quality and Save Money

Whether developing camp sites for visitors or restoring stream habitats, work on national forests often involves disturbing the ground, which creates opportunities for sedimentation and other negative water quality impacts. Best management practices are techniques that help control and reduce water pollution and protect aquatic ecosystems.

Forest Service scientists pioneered the first national program to strengthen implementation and monitoring of best management practices (BMP) used to protect water quality from the diverse range of ground disturbing and management activities that occur on national forest system lands. The national BMP monitoring program provides consistency for evaluating BMP implementation and effectiveness across all National Forest System units, which, in turn, allows the Forest Service, for the first time ever, to report national performance results to regulatory agencies, States, Tribes, other stakeholders, and the public. The consistency of the monitoring program is expected to result in improved water quality and millions of dollars of savings through simplified and streamlined monitoring approaches that contribute to the success of both local and national adaptive management strategies.

7.1. 2019 Fire & Fuels Technology Updates Fire and Aviation

The results of Forest Service fire research help society address the ongoing challenges of living with wildland fire.

Background

"Science Serving Society" is the motto for USDA Forest Service Research & Development. Forest Service fire scientists, analysts, and technology transfer specialists work to put science in the hands of managers, decision makers, policy makers, homeowners, and communities.

The results of Forest Service fire research come in many forms, from user-friendly software and data to real-time support trained analysts on active wildfires, to educational materials for school children.

Research Highlights

Smoke forecasting systems: Even low-intensity prescribed fires can have adverse effects on air quality and human health. Smoke modeling tools integrate meteorological data, cutting edge smoke science, and fire behavior predictions to help fire managers schedule essential prescribed burns to minimize these health impacts.

Decision support for treating wildland fuels: Forest Service research provides methods to answer questions such as: Which communities are most at risk to fire?

What fuel treatments will be most effective at reducing the risk of severe fire?

How can forests be restored to a healthier condition where fire plays a positive role?

How and where should scarce funds be best invested to reduce the negative consequences of fire?

Fire and fuels research provides the scientific foundations to a *National Cohesive Wildland Fire Management Strategy*, a cross-jurisdictional strategy to restore resilient landscapes, create fire-adapted communities, and respond to wildfire.

Smoke Updates

Airnow - https://airnow.gov/index.cfm?action=topics.smoke_wildfires - used by Air Resource Advisors to model and create public smoke forecasts, compliant with S.47 Dingle Act of 2019.

Monitoring 4.1- https://tools.airfire.org/monitoring/v4/#!/?category=PM2.5_nowcast&centerlat=42&centerlon=-95&zoom=4 - another tool used to analyze the trends in particulate matter produced during wildfire events that assists in forecasting impact areas and advising precautions to public health.

Risk Assessment & Vegetation Mapping Tools

LANDFIRE - https://www.landfire.gov/lf_remap.php -updating of LANDFIRE layers and development of analysis tool.

Fire Sciences Laboratory (list) **https://www.fs.fed.us/research/wildland-fire/**

7.2. Science Delivery bv the R&D Washington Office and Field Research Stations

R&D's Washington Office provides leadership, conducts strategic planning, and ensures scientific integrity. Washington Office R&D program staff also develop national research policy priorities and directions and communicate them to resource planners and land managers within the agency, as well as to other government agency employees, academics, personnel from nonprofit organizations and industry, and the public.

Inventory, Monitoring, and Assessment Research

Through data collection, analysis and research, Inventory, Monitoring, and Assessment (IMAR) produces the authoritative information to inform strategic-level decision making related to forest management and conservation, forest policy and forest investments. IMAR also provides the expertise in enhancing earth observation methodologies ranging from global to local scales. IMAR products are key for assessing forest sustainability and provide a basis for analysis and research at multiple scales. The

information is used by a broad spectrum of interests and communities, including forest owners; county, State, Federal, and Tribal leaders; non-governmental interest groups; investors; and private firms.

IMAR work focuses in four areas: (1) Forest Inventory and Analysis Program (FIA); (2) Resources Planning Act (RPA) Assessment; (3) Sustainability Assessment: and (4) Remote Sensing and Geospatial Analysis Research. In partnership with Forest Service International Programs, IMAR also provides leadership and coordination for international monitoring and assessment activities to the United Nations Food and Agriculture Organization's (FAO) Global Forest Resource Assessment, the FAO North American Forestry Commission, the United Nations (UN) Economic Commission for Europe Committee on Forests and the Forest Industry, the UN Forum on Forest, the Canadian Forest Service, and various U.S. agencies for international development activities.

Forest Inventory and Analysis Program

Since 1930, the Forest Inventory and Analysis (FIA) program has been building the largest continuous dataset on forest resources in the world. Through consistent inventory processes, FIA data are widely used to address local and regional issues related to trends in forest extent, health, and productivity; land cover and land use change; the changing demographics of private forest landowners; and industrial and non-industrial uses of timber. Forest inventories have expanded their primary supporting role in decision making from forest products and economic development in the last century to a wider range of ecosystem services today, including carbon, water, recreation, wildlife habitat, biodiversity, and human health. Hundreds of public and private entities – from State forest agencies to academic institutions to

timber management companies – rely on FIA to generate authoritative protocols and data, conduct applicable research, and operate businesses.

The FIA program conducts forest inventories in all 50 States and U.S. territories. Field plots have been collected on approximately 90 percent of the U.S. forestlands, with the remaining 10 percent in parts of interior Alaska yet to be surveyed. Although plot-based field surveys provide information concerning existing forest conditions, additional surveys such as the timber product output (TPO) provide information on commercial product generation and the National Woodland Owner Survey (NWOS) on the characteristics and management objectives of the Nation's private woodland owners.

Resources Planning Act Assessment

The Resources Planning Act (RPA) Assessment conducts research on the current status and trends and projected futures of forest and rangeland renewable resources. The RPA Assessment is mandated by the Forest and Rangeland Renewable Resources Planning Act, covering resources on all ownerships. The assessment examines how the interaction of socioeconomic and biophysical drivers affects the productivity of forest and rangeland ecosystems and their ability to meet increasing demands for goods and services, including analyses of forests, rangelands, forest products, wildlife and fish, biodiversity, water, outdoor recreation, carbon, land use, and urban forests.

Sustainability Assessment

The Sustainability Assessment program conducts research on criteria and indicators of forest sustainability to provide a comprehensive evaluation of forest conditions in the United States as they relate to the ecological, social, and economic dimensions of sustainability. Forest sustainability is directly tied to the Forest Service's core mission, and understanding whether forests are sustainable at the national level is important because such understanding is needed to guide national policy formulation, it can take a long time to improve forest conditions, and trade of wood products domestically and internationally increasingly expects sourcing from sustainable forests.

The United States is updating its National Report on Sustainable Forests, last compiled in 2010. The report uses a criteria and indicators framework (The Montréal Process Criteria and Indicators) for describing forest conditions and their associated values, characterizing the essential components of sustainable forest management. These internationally agreed-upon criteria and indicators were developed collaboratively with other Montreal Process member countries as a shared response to the pressing need for sustainable forest management.

Remote sensing and geospatial analysis research

Emerging remote sensing datasets and technology advancements are foundational to increasing the FIA program's efficiencies and meeting broader user needs. These efforts are also central to implementing Section 8632 of the 2018 Farm Bill, which directs the agency to continue to increase efficiencies in the operations of the FIA program through the use and integration of advanced remote sensing technologies, as well as through partnerships in this arena. Using remote sensing, National Forest Inventory precision

targets can be resolved at a smaller landscape scale, typically resulting in better forest inventory estimates and translating into cost savings. Currently, free and public satellite data, such as from the USGS-NASA Landsat constellation, and data from the National Agriculture Imagery Program (NAIP), are used to complement FIA activities. Airborne and satellite Light Detection and Ranging (LiDAR) are remote sensing technologies that are increasing FIA's data collection efficiencies in remote or inaccessible areas. LiDAR and stereo digital imagery offer great potential but require higher skillsets and greater storage and computational needs. Advances in machine learning and GIS technology have partially addressed these challenges and improved efficiency of FIA estimation procedures.

FIA leads implementation of policy change on agreements

In FY2020, the FIA program adopted changes to ensure that confidential information annually collected through the program's surveys on field plots, landowner characteristics, and timber product output from mills, was protected to the full extent of existing laws when entering into agreements with third parties. In addition, revising the traditional way of entering into formal partnerships ensured the acknowledgement and recognition to FIA of all products and derivatives built from FIA data and produced by third parties. In addition to best protecting FIA assets, this policy change also would demonstrate to our partners and clients the extent of their investments in products produced in partnership with other institutions. These objectives led to the search for legally binding instruments and a revision of long-established agreement practices as the new way to conduct business.

In an effort to protect 325,000 plot locations across 50 States and U.S. islands, landowners' personally identifiable information, non-public corporate data, and unpublished information, FIA adopted the use of Material Transfer Agreements (MTAs) and Cooperative Research and Development Agreement (CRADA) as the exclusive agreement types to sign when transferring FIA confidential data to a third party. FIA also adopted the use of the Memorandum of Agreement (MoA), replacing the previously used overarching instrument, the Memorandum of Understanding (MoU), because the legally binding nature of MTAs, CRADAs, and MoAs holds parties accountable for the commitments and terms established in these conditional agreements.

FIA's efforts to protect the program has led to a permanent policy change in the Forest Service Handbook, which defines the agency's official protocol for the use of MTAs and CRADAs by the entire Forest Service. We anticipate that more FS programs will follow FIA's pioneering steps in the adoption of these legally binding instruments when entering into agreements with third parties as a way to ensure that agreed terms are met, to better clarify responsibilities among parties, and to support these partnerships in the long term.

In 2020, FIA executed its first CRADA, with the Environmental Systems Research Institute (ESRI), as well as executed 20 new MTAs and 3 national MoAs.

Recent achievements by IMAR staff and FIA units located at the research stations

- *Supplied over 240 spatial data requests and almost 4.5 million online data requests and responded to almost a thousand consultations, investing 7,764 hours of staff time* – Through online applications, the Spatial Data Service Team, and subject matter experts, FIA addresses the growing informational needs related to forest conditions, forestland ownership, and timber product generation.

- *Published the estimated carbon loss due to tree mortality caused by the most damaging non-native insects and diseases in U.S. forests* – This work demonstrates the value of FIA data to assess broad-scale changes in forests and indicates that forest pest invasions, driven primarily by globalization, are creating a large risk to U.S. forests and have significant impacts on carbon dynamics. Increased tree mortality from the impacts of alien insect and diseases results in the transfer of carbon stored in live trees into dead material, much of which will eventually return to the atmosphere. Results show that non-native forest pests threaten an estimated 76 percent of carbon sequestration in North America that comes from forests.

- *Increased awareness and use of FIA data by managers of national forests in several regions* – These efforts have enhanced national forest managers' understanding of FIA data and how to best use it in the management, project development, vegetation mapping, and broad-scale monitoring of the National Forest System. Published two related articles (Wurtzebach, 2019 and Hoover, 2020).

- *Published the analysis of the causes leading to carbon stock changes across the National Forest System* – For the first time, baseline assessments of carbon stocks in every national forest incorporate detail on the causes of carbon stock change, including timber harvesting, insect outbreaks and diseases, aging, climate variability, increasing atmospheric carbon dioxide concentrations, and nitrogen deposition. Previous baseline assessments of carbon stocks evaluated observed trends based on forest inventory data but were limited in their ability to reveal detailed causes of these trends. Results support national forest units in assessing carbon stocks, quantifying carbon outcomes of broad forest management strategies and planning, and meeting carbon assessment requirements of the 2012 Planning Rule and directives.

- *Developed and published the theoretical basis for the NASA Global Ecosystems Dynamics Investigation (GEDI) mission's estimates of global forest biomass* – This research brings a new level of accuracy to understanding the role of forests in the global carbon cycle. Most uses of spaceborne LiDAR for biomass estimation have ignored formal modes of uncertainty estimation. GEDI is the first mission designed around forest sampling considerations. FIA scientists used specially collected field and airborne LiDAR data to test a hybrid model-based statistical estimator that GEDI will use globally.

- *Published the analysis of herbaceous species widespread vulnerability to atmospheric deposition of nitrogen and sulfur in the United States* – In collaboration with U.S. Environmental Protection Agency, universities, and the U.S. Geological Survey, FIA scientists found that about 70 percent of herbaceous species in the United States are at risk from atmospheric depositions of nitrogen

and sulfur. Results from this analysis can inform improvements to air quality policies in the United States and globally.

- *Developed and published a new method using drones with lasers and aerial photos to complement field surveys in forest monitoring* – The new method aids forest inventories using advancements in photogrammetry and market sensors and platforms to incorporate an unmanned aerial systems-based approach into existing forest monitoring.

- *For the first time, estimated greenhouse gas emissions and removals from managed forest land in Alaska from 1990 to 2017*– Including all managed forest land in Alaska in the 2019 U.S. GHG inventory establishes important baseline estimates for this region, provides a more complete characterization of GHG emissions and removals in the United States, and helps identify opportunities for mitigating GHG emissions in Alaska and other remote areas with limited information. Managed forests in Alaska represent 10 percent of the total managed forest land area in the Nation, but store 17 percent of the total carbon in forests. These forests also represent a net carbon sink over the last 27 years but there is considerable interannual variability driven, in large part, by wildfire. Emissions from severe fire years in Alaska substantially reduce the contribution of U.S. forests as a carbon sink in those years.

- *Published a methodology to improve the inventory of mangrove forests in the United States.* – In collaboration with NASA and Mexico's National Forestry Commission, FIA tested different methods for mangrove inventory in Florida. Results of this analysis offered solutions to

overcome challenges related to ground measurements, including accessibility issues, time constraints, and hazardous conditions.

- *Published an assessment of the status of white oak advanced regeneration in forests of Kentucky and Tennessee* – The assessment provides a better understanding of white oak (*Quercus alba* L.) regeneration and will assist forest management decisions to decrease the risk of current decline of oak forests in the Eastern United States. Much of this decline can be traced to maturing forests (succession), species replacement, cutting, and ineffective fire management.

- *Published reports to support development of the upcoming RPA Assessment* – These reports examine the changing composition of the U.S. land base and establish plausible scenarios for future U.S. socioeconomic growth and climate change. This information sets the stage for resource analyses in the RPA Assessment.

- *Developed data guides and catalogs to help land managers use information from the RPA Assessment to support planning and decision making* – In particular, the catalogue will assist addressing the requirements of the 2012 Planning Rule by connecting the Planning Rule assessment topic areas and directives with relevant datasets, tools, reports, maps, and other information from the RPA Assessment.

- *Published national-scale forest sustainability indicator reports on biotic and abiotic forest disturbance, and on soil and water conditions on forest lands* – The published reports updated

seven of the 54 indicators internationally agreed to by the Montreal Process, an international effort assessing sustainable forest management and providing a framework for describing the value and condition of participant nations' forests.

- *Completed Voluntary National Report from United States of America to the United Nations Forum on Forests 15* – Major contributor and source of information for reporting on progress toward the implementation of the United Nations strategic plan for forests 2017–2030, the United Nations forest instrument and voluntary national contributions.

- *Provided statistical reports for USDA Annual Agricultural Statistics Report, UN Sustainable Development Goals, and the UN Economic Commission's annual Joint Forest Products Questionnaire* – Of these, the UNECE work is the most extensive, involving annual collation and estimation of production and trade statistics for the U.S. wood products sector and all of its constituent product categories.

A Role Model for Federal Accountability: The FIA Annual Business Report - BLOG

https://www.fs.usda.gov/features/role-model-federal-accountability-fia-annual-business-report

Urban Sustainable Research

In dense urban centers, a city's treescapes (or lack thereof) have a big impact on the quality of life. A unique government and academic partnership uses Lidar and GIS technology to help communities map, assess, and monitor their urban tree canopy. https://www.gisforscience.com/chapter11/

Baltimore Field Station

FS report on the financial and technical analysis for Baltimore City's Wood Sort Yard (funded by S&PF urban and community forestry) resulted this fall in an internal Baltimore City Innovation Grant for ~$900k and will lead to 8 new jobs.

https://www.fs.usda.gov/inside-fs/delivering-mission/deliver/baltimore-urban-wood-project-seeks-transform-waste-wood

http://baltimorewoodproject.org/pdf/FreshCut_BaltimoreUrbanWood_v3_2019.05.14.pdf

http://baltimorewoodproject.org/

Sustainable Forest Management Research

Sustainable Forest Management Research builds a solid scientific foundation for natural resource management and policymaking at multiple spatial scales in forest and rangeland ecosystems in the

United States and globally. Methods used include conducting leading-edge research, synthesizing existing research, and improving access to and highlighting field research. The program:

- Investigates natural disturbances, stressors, and threats caused by insects, diseases, and invasive species; fire; weather (hurricanes, ice storms, droughts); and physical phenomena (avalanches, landslides, volcanoes) that impact forests and grasslands.

- Studies human-caused disturbances, stressors, and threats related to fragmentation of forests and rangelands and changing weather patterns (temperature and precipitation), atmospheric deposition, air quality, and soil health.

- Researches sustainable production of forest and rangeland resources.

- Manages systems, practices, and policy options for restoring forests, rangelands, and agroforestry systems.

- Researches and manages landscape ecology issues at national, regional, and local levels.

- Researches meteorology and the effects of climate variability on living organisms.

- Conducts vulnerability and risk assessments.

- Conserves biological diversity using methods such as genetics, gene conservation, and species conservation.

- Develops reforestation and revegetation methods and materials.

- Manages experimental forests and ranges, research natural areas, and demonstration areas.

Recent achievements

The FY 2020 ***Effects of Drought on Forest and Rangelands of the United States: Translating Science into Management*** assessment builds upon the award-winning *The Effects of Drought on Forest and Rangelands of the United States: A Comprehensive Science Synthesis*. The management synthesis was undertaken at the behest of the National Forest System, completed in a six-month timeframe with 50 authors from Federal and State agencies and other experts. This innovative use of the IPCC approach has resulted in significant savings. To date, key assessments on climate change, drought, agroforestry, non-timber forest products, smoke, invasive species, genetics, and soils have resulted in $7 million in savings for R&D.

The USDA Climate Hubs provided outreach and technical support to Federal employees and stakeholders through 76 webinars, 161 presentations resulting in 60,000 web site visits, 366 Tribal engagements, and workshops engaging 6,802 participants. This outreach and support enhanced understanding of climate vulnerabilities and adaptation strategies and led to better integration of

adaptation considerations into State Forest Action Plans in Connecticut, New Hampshire, and Michigan; identification of regional carbon sequestration strategies; creation of a regional drought learning network for the Southwest; and development of climate adaptation strategies for the Pacific Northwest.

Addressing COVID-19 Pandemic Issues: Co-signing an agreement among the Centers for Disease Control (CDC), = Forest Service R&D, and State and Private Forestry, led to the development of a Smoke COVID Dashboard to better understand and communicate wildfire smoke and Coronavirus COVID-19 effects in communities during the 2020 wildfire season. In addition, we have led the effort in collaboration with the Department of Energy to leverage funding from the International Energy Agency Task 43 to investigate potential COVID-19 disruptions to the biomass supply chain for energy production in the United States.

Forest and Rangeland Soils of the United States Under Changing Conditions: FS R&D released the newly published soils assessment on World Soils Day—December 5th. The book, *Forest and Rangeland Soils of the United States under Changing Conditions,* is an open access, multi-authored synthesis of leading-edge soils research, tools and technologies, and management strategies for the United States and affiliated territories. The . Forest Service Research & Development-led science synthesis engaged 80 authors from 26 agencies and institutions addresses a broad range of subjects, and includes more than 1,000 reference citations. The book includes an overview of the state of forest and rangeland soils research in the United States and summarizes leading edge science

regarding soil carbon, hydrology, biogeochemistry, and biological diversity and the effects of natural and human-caused disturbances.

Library of Silvicultural Prescriptions and a Scenario Investment Planning (SIP) Tool: We developed a Library of Silvicultural Prescriptions and a Scenario Investment Planning (SIP) tool that compares the benefits of specific prescriptions for forest resilience, fire adaptation, and economic impact objectives.]The Forest Service is using SIP to set national investment priorities using the "Fire Shed Registry" approach,applying 250 silvicultural prescriptions covering over 300 million acres to inform the 3.5 million-acre NFS target to reduce hazardous fuels and improve forest conditions.

Shared Stewardship: We have strengthened regional implementation of agroforestry through regional agroforestry working groups across the United States. This included providing leadership and support for the Southwest Agroforestry Action Network (SWAAN), Pacific Northwest Agroforestry Working Group, Northeast/Mid-Atlantic Agroforestry Working Group, Appalachian Beginning Forest Farmer Coalition, the newly formed Southern California Agroforestry Working Group, and the American Forest Farming Council.

Agroforestry Best Management Practices Developed: We have developed protocols for the application of agroforestry best practices and improved stakeholder experiences in the forest farming community by developing new region-specific educational materials and producer profiles of agroforestry in States such as California, Wisconsin, Ohio, West Virginia, North Carolina, and

Virginia. Despite a challenging year, we have made significant progress in assisting national forests and the forest sector by providing leading-edge research to assist timber production through improved forest planning and by providing new research on best management practices for drought and soil management for improving productivity in both rural and urban landscapes.

Climactic Variability and Change on Forest Ecosystems: *A Comprehensive Science Synthesis for the U.S. Forest Sector*—a technical report for the U.S. Global Change Research Program National Climate Assessment. This publication provided the foundation for an award-winning book, *Climate Change and United States Forests*, which was edited by FS researchers and serves as a comprehensive science-based assessment of the effects and variability of a changing climate on U.S. forests to date.

Tree Breeding and Forest Genetic Resources: The first U.S. comprehensive assessment on Forest Genetic Resources of the United States of America will be published in early 2021 as the U.S. input to the U.N. Food and Agriculture Organization's 2023 World Genetics Report. Authored by 60 national experts, the report supports the USDA Secretary's vision for the Ag Innovations Agenda and strengthens USDA and private sector ties resulting in improved forest conditions, by providing access to public and private genetics tools and technologies, forest genetics innovations, tree breeding and management advances, and solutions to impacts from a changing condition.

Heir's Property Ownership Study: Partnering with USDA Agencies, NGOs, the African American Land Retention Program and the Minority Landowner group, we completed a landmark study on the

challenges surrounding heirs' property ownership, especially those in underserved communities such as African Americans living in counties adjacent to national forests in the South and rural Appalachia.

Climate Hub Publications: The USDA Climate Hubs also produced 36 peer reviewed articles and 202 other articles for the public to enhance climate literacy and understanding of strategies to enhance forest, rangeland, farm and community resilience, including summarizing climate vulnerabilities and adaptation options for each of the national forests in the Southeast United States, a Climate Change Primer for Forest Managers in the Sierra Nevada, and a guidebook on hurricane resiliency for pine forest landowners.

Pending national publications in 2021

Invasive Species in the Forests and Rangelands of the United States, to be published in 2021

Wildland Urban Interface: Forests and Rangelands in a Changing Environment, to be published in 2021

Wildland Fire Smoke in the United States: A Scientific Assessment, to be published in Spring 2021

Landscape Restoration and Ecosystem Services Research

Landscape Restoration and Ecosystem Services Research (LRESR) conducts innovative and seminal research that provides sound science, innovative technologies, and practical applications to improve the health and productivity of our Nation's forests and grasslands, inform natural resources policy and land management decisions, and anticipate emerging natural resource issues.

The Landscape Restoration & Ecosystem Services Research (LR&ESR) staff has leadership responsibility in the R&D mission area for five broad lines of inquiry:

- Providing renewable natural resource managers and policy makers with management and policy options that promote healthy, resilient, watershed conditions and wildlife and fish habitats.

- Designing new approaches to "green" investment and development that have lower impacts on the environment and that create sustainable economic development, increased employment, and healthy communities.

- Exploring how settings with trees all along the urban-to-wildland gradient create values for people—whether neighborhood residents or the recreation visitor—and how to practice more effective stewardship to enhance and sustain these values.

- Creating deeper understanding of how emerging technologies, products, and markets, along with changing economic and societal values, impact forests and the goods and ecological services they provide.

- Inventing wood-based materials that create new markets or expand existing markets, including inventing advanced manufacturing and conversion processes for utilizing woody biomass and recycled materials.

The prime objective for LR&ESR staff members across these five lines of inquiry is to build through syntheses and advocacy of field scientists' findings a solid scientific foundation for natural resource management and policy-making at multiple spatial scales in boreal, temperate, and tropical forest ecosystems.

Recent achievements

eDNAtlas: The eDNAtlas is an open-access online database that provides precise spatial information on the occurrenceand locations of aquatic species in the United States., as determined by eDNA sampling. The eDNA samples constituting the database are collected using a standardized field sampling protocol by numerous natural resource agencies and non-governmental organizations partnered with the USDA Forest Service National Genomics Center for Wildlife and Fish Conservation. The eDNAtlas database currently contains results from thousands of sites and dozens of species and will be annually updated with additional results for a growing list of species.

Bat Genomics Database: The USDA Forest Service RMRS National Genomics Center (NGC) is developing a Bat Genomics Database. The goals of this database are to create a national genomics repository for North American bat species for accurate species identification and to develop more sensitive Pd detection methods to trace origins of the fungal pathogen across the United States whether by natural dispersal or due to human assistance. NGC is also interested in developing the tools to collect bat and Pd eDNA from fresh watershed samples.

Economic Valuation Protocol for Recreation: Developed a scientifically valid protocol and data tables for calculating economic value of recreation on national forests, including a webinar and guidance document for training planners, managers, and specialists in the use of the method. The method is being rolled out this year.

Timber Appraisal Methodology: Developed a new method for timber appraisal to account for contemporary market conditions and prices so that fair market prices can be implemented to ensure positive bids and contract awards that generate timber revenue while improving forest health conditions. The method is under testing with positive results thus far.

Urban Forest Connections: Hosted nine webinars (https://www.fs.fed.us/research/urban-webinars/) that showcased research and best practices on topics ranging from integrating trees into stormwater management design to studying the impact of trees and green space on cardiovascular health. These webinars had an average of 214 attendees per session during the live webinars, and are available for download after the fact, reaching countless more practitioners.

Illegal Marijuana Site Detection: R&D scientists built a remote sensing model that can identify illegal marijuana grow sites from satellite imagery. They combined standard and novel technologies to "find the needle in the haystack." Advanced image classification algorithms can sort a few hundred acres of illegal trespass grow operations from millions of acres. The system enables us to identify specific location coordinates of trespass grows and the detection of grow sites when it is not the growing season, making it useful to both law enforcement and ecological conservation priorities.

Monarch Habitat Management: Developed the technical transfer of materials concerning milkweed (*Asclepias* spp.) propagation and monarch butterfly waystation establishment, as well as field trials to determine feasibility of outplanting rhizomes of milkweed to support monarch butterfly populations. Monarchs cannot survive without milkweed; their caterpillars only eat milkweed plants, and monarch butterflies need milkweed to lay their eggs. Milkweed has been in decline in recent decades.

e-Nose: The electronic-nose (e-nose) is a relatively new diagnostic tool that has been used successfully for early detection of disease-associated biomarkers in certain human diseases. SRS researchers are working to adapt e-nose for early detection of animal disease pathogens such as *Pseudogymnoascus destructans* (Pd), the causative agent of white-nose syndrome (WNS) and the prions that cause chronic wasting disease (CWD). The e-nose is a non-invasive tool that conducts highly-specialized chemical analysis of infected animals before they show clinical signs of disease which could reduce the incidence of disease transmission.

Bat-AMP and NABat: PSW and SRS scientists have developed the Bat Acoustic Monitoring Portal (Bat AMP) and the North American Bat Monitoring Program (NABat Program), respectively, for monitoring the status of bat populations on the landscape over time. Both databases are collaborative efforts to share bat population data across multiple federal and state agencies.

Improved Efficiency of Blister Rust Screening Technique: White pine blister rust is an invasive pathogen that kills white pines, including the revered and high-value Sugar pine. Years ago, PSW research discovered there is a major gene for resistance. A process was developed to screen seedlings to determine if the parent has the gene, and the technique has been used ever since to identify seed sources for reforestation; however, the process takes over a year, with only a 1-10 percent success rate. Recent genome sequencing research discovered five locations (markers) on the genome were potentially associated with the gene for resistance. Our research scientist realized the potential of these markers developed the markers, tested them, and demonstrated that 70-90 percent of the time the markers correctly identified resistant and non-resistant trees, allowing for candidate trees to be identified within one day and resistant seed sources to be identified with 100-fold efficiency.

Knowledge Management and Communications

The Knowledge Management and Communications (KMC) staff's mission is to disseminate results of the agency's research to varied audiences—including the scientific community, land owners/managers, academics, policy-makers, the public and students—and to provide the information technology needed to disseminate results. KMC is responsible for leadership, development, oversight, and delivery of

communications, performance accountability, science applications, science education, data quality, peer review, tech transfer and licensing activities and information management for Forest Service Research & Development. KMC also defines, develops, and maintains the national information architecture and content of databases essential to managing the strategic information flow and messaging about FS research.

- Plays a leadership role in the Forestry Research Advisory Council (FRAC) Federal Advisory Committee. Consisting of up to 20 members appointed by the Secretary of Agriculture from federal, state, university, industry, and nongovernmental organizations, the FRAC meets annually and presents recommendations to the Secretary on the Forest Service R&D program.

- Provides information technology resources for communicating research, including the R&D website, which provides public access to more than 50,000 scholarly publications authored by R&D scientists and collaborators.

- Maintains databases of research and archives information.

- Develops and disseminates science applications.

- Manages R&D data quality, peer review, and performance accountability.

- Manages R&D patents, licensing, and technology transfer.

- Manages the Forest Service History Program.

- Produces the Natural Inquirer, a free science education journal for students.

- Manages R&D's science delivery and communications program, which produces products and services that target varied audiences, including the scientific community, land managers, policymakers, the public and other stakeholder groups; this work involves overseeing the strategic planning and production of web and hard copy communications products, new outreach products, communications promoting the rollout of major R&D initiatives, and the translation of technical information into reader-friendly language.

Recent achievements

R&D WO Newsletter: Produced 12 monthly newsletter issues on time. Recruited 1,660 new subscribers in 2018, including leaders in the Forest Service and partner organizations and Congressional staffers. Currently have about 11,000 subscribers. Infographics featured in newsletter are multi-purposed and are among the Office of Communication's most popular social media features.

Rollouts of Reports: Wrote communication plan for agroforestry report and helped execute plan, which helped agroforestry report score in top 5 percent of all research outputs rated by Altmetric. Wrote first draft of communication plan for Non-Forest Timber Products. Helped coordinate rollout of PNW Forest Plan Science Synthesis.

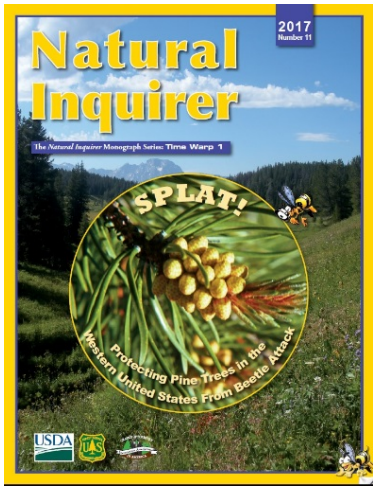
Research Highlights: 105 highlights were reviewed, edited, and will be made available on the web.

Other High-Impact Products: Produced three new glossy handouts: 1) R&D research for NFS; 2) illegal marijuana grows and 3) fire research. Also produced "A Sample of Recent Research Accomplishments: Science and Innovation for a New Century of Conservation." Informally called "Greatest Hits," this document--a summary of R&D research achievements—is in production. Large sections of this document were incorporated into a Charles Riley Memorial Foundation document that describes the importance of R&D.

Altmetrics: Expanded the coverage to track mentions of research outputs as offered on five station websites. Produced 45 weekly reports of "most mentioned" R&D research outputs. Reports were originally used to brief R&D Deputy Chief for weekly meetings with the Chief but were modified to assist public affairs officers in what marketing approach led to improved visibility of Forest Service research results.

Facebook and Inside the Forest Service: Provide postings for these outlets on a weekly basis.

Web Modernization: Reached agreement on the design, taxonomy and content types that will, together, define the information architecture and appearance of a common web infrastructure. The new solution will consolidate ten of R&D's websites into a modern searchable solution offering hundreds of thousands of pages of rigorous, science-based content all under a common department brand.



The *Natural Inquirer* program creates and distributes re-usable science journals and materials written for K-12 students. In FY 2020, approximately 157,602 of these products were distributed to classrooms, homeschools, and individuals across the country. It is notable that the COVID19 pandemic affected our work during FY 2020. All work is done with our non-profit partner, the Cradle of Forestry in America Interpretive Association (DBA FIND Outdoors), and the University of Georgia.

http://naturalinquirer.org

Important FY 2020 program accomplishments

The following products were distributed in FY 2020:

- 97,318 scientist and engineer cards
- 724 "America's First Forest" DVDs
- 78 Social Scientists Packs (Four journals and thirteen cards)
- 142 *Natural Inquirer* Reader Packs (Eight readers and seven cards)
- 7,002 *Natural Inquirer* Readers

- 5,990 *Nature Science Investigator(NSI)*

- 11,619 *"Bee" A Scientist* coloring book

- 4,823 *"Bee" A Fire Scientist* coloring book

- 3,330 Advanced Fire Scientist coloring book

- 174 Spanish *Natural Inquirer* products

- 60,284 *Natural Inquirer* publications

- 157,602 GRAND TOTAL for all *Natural Inquirer* products

Social Media Presence & *Natural Inquirer* website

- Experienced significantly increased engagement rates in August due to distance learning offerings, back-to-school, and new coloring books: 123% increase in Twitter engagement and 900% increase in Facebook engagement.

- Started a *Natural Inquirer* Instagram account

- 93,463 unique visitors to *Natural Inquirer* website

New products

- Logjams and Beaver Dams monograph (Topic: carbon storage)
- Caves and Karst *Natural Inquirer* journal
- "Bee" A Fire Scientist coloring book
- Advanced Fire Scientist coloring book

Natural Inquirer products distributed at the following events (Please note this list only captures some of the events where NI materials are distributed, and due to COVID19 many events were cancelled.)

- Project Learning Tree/Project Wild training
- Forest Service Conservation Education Halloween event
- Georgia STEM Forum
- National Science Teachers Association National Conference

- Cradle of Forestry in America (CFAIA) visitor sites & campgrounds
- CFAIA Pisgah Explorers Club
- NAAEE conference
- Kent State University
- Forestry Institute for Teachers (FIT)
- 4-H Arkansas
- Rensselaer Polytechnic Institute spring career fair
- Davidson River Campground, Pisgah National Forest
- NYC Watershed Ag Council, Forestry
- Tennessee State University 4-H

Partnerships

- Forest Service Conservation Education

- 4-H (Forest and Agriculture monograph series)
- Forest Service National Symbols program (Woodsy Owl)
- Forest Service International Institute of Tropical Forestry
- National Agroforestry Center

National Agroforestry Center

Established in the 1990 Farm Bill, the National Agroforestry Center advances the health, diversity, and productivity of working lands, waters, and communities through agroforestry. The Center provides science-based information for integrating trees and agriculture on farms, forests, and ranchlands across the United States, to improve water quality, enhance crop and livestock production, create wildlife habitat, and sequester carbon. Located in Lincoln, Nebraska, the Center works with a national network of more than 4,000 natural resource and agriculture professionals who, in turn, provide technical assistance to farmers and landowners.

Work at the Center includes research and/or outreach on the five agroforestry systems most utilized in the United States:

- Windbreaks and shelterbelts, to shelter crops, people, animals, buildings, and soil from wind, snow, dust, and odors.

- Riparian forest buffers that filter farm runoff, reduce soil erosion, and diversify income sources;

- Silvopasture, to increase the efficiency of grazing, pasture and forest land uses, and to diversify incomes;

- Alley cropping to incorporate annual or perennial crops into the management of trees, thus augmenting landowner income before trees are mature enough to harvest and/or produce fruit, berries, or nuts; and

- Forest farming, or multi-story cropping, to produce food, herbal, botanical, or decorative crops under the protection of a managed forest canopy**.**

Efforts in FY 2020 included expanding outreach and information transfer through support for partner organizations to develop regionally-specific educational materials on agroforestry practices. Topics funded this year include forest farming in Appalachia, agroforestry in the Midwest, and silvopasture in California. The Center also funded projects to develop outreach materials related to urban agroforestry in Texas, Hawaii, and Washington D.C. In addition, new publications have been produced on land access for agroforestry, soil health, and other agroforestry topics. Research advances have included publishing and presenting research from a systematic review on pollinators in agroforestry systems,

continued development of inventorying trees outside forests (TOFs) using high-resolution land cover images, and setting the stage for future agroforestry assessments through a national survey of agroforestry adopters.

Northern Research Station

The Northern Research Station provides the science land managers, city planners, and policy makers need to improve the condition of the Nation's forests and grasslands. In a region extending from Maine to Minnesota and from Missouri to Maryland, Northern Research Station science aims to understand all the elements of forests and related landscapes. The Northern Research Station is one of seven Forest Service research units conducting research within all 50 States as well as in U.S. territories and commonwealths.

Northern Research Station scientists reach these audiences in a variety of ways, including:

- Participation in and contribution to hundreds of consultations with national forest and state forest managers and other partners in efforts to improve access to and use of Station science.

- Publishing in peer-reviewed journals and Station technical reports; providing access to over 15,000 publications authored or co-authored by current or former Northern Research Station scientists.

The Station develops web-based tools that deliver sound, peer-reviewed science in a format that is convenient for land managers and others.

The Northern Research Station's Forest Inventory and Analysis group is responsible for inventory and monitoring in 24 States. The Forest Inventory Data Mart and other tools deliver extensive data, providing stakeholders in State agencies, private industry, and other Federal agencies alternatives for generating tables and maps.

The Station manages 22 of the 81 experimental forests that are part of the FS Experimental Forest Network; most of these long-term research sites lie within national forests. The ability to conduct scientific research in-house, to apply research findings on National Forest System lands, and to transfer these findings to others for use on all the Nation's forest land sets the Forest Service apart as a natural resource agency.

DRS Science Delivery

Scenarios for compound disasters: COVID-19 and wildfire management

Simultaneously combatting the wildfire-like spread of COVID-19 and actual wildfire is an unprecedented challenge for wildfire management agencies, with impacts on nearly all aspects of firefighting, from training new fire crews to evacuating residents from fire zones. At the request of the Enterprise Risk Management Response Team established by the Executive Leadership Team of the USDA Forest Service to look at this issue, the Strategic Foresight Group at the Northern Research Station rapidly developed scenarios to inform wildfire planning and decision making. Scientists interviewed firefighting and strategic foresight experts and framed four scenarios: "Necessary redirection" (high COVID-19 risk, low fire risk), "Compound disasters" (risk from COVID-19 and fire are both high), "Enlightenment" where both risks are low, and "Normal interrupted" with lower COVID-19 but high fire risks. The "Compound disasters" scenario already had decision makers' attention. But "Normal interrupted" highlighted the possibility of complacency regarding COVID-19 risks. "Enlightenment" captured experts' hopes that a silver lining might be found but would represent a fundamental change in the approach to fighting wildfire, allowing more acres to burn.

Potential to increase carbon sequestration with tree planting

A Northern Research Station scientist led the most in-depth study to date on how increasing the number of forest trees might offset carbon emissions in the United States. To mitigate tree loss and offset carbon emissions, several initiatives are under way to increase tree planting in forests and landscapes that are not technically defined as forests, such as urban forests. To determine carbon emissions offset from approximately 1.38 trillion trees currently growing in the conterminous United States, researchers examined publicly available data from more than 130,000 forested plots from the national forest

inventory conducted by the Forest Inventory and Analysis Program. Forests and harvested wood products annually offset the equivalent of more than 14 percent of economy-wide carbon dioxide emissions in the Nation, however, almost 33 million hectares of productive forest land are understocked with trees. Fully stocking all understocked productive forest land with trees could increase carbon sequestration by approximately 20 percent. These findings suggest that concentrating tree planting on understocked productive forest land may substantially increase carbon sequestration capacity in the United States.

New guidance on long-term urban tree monitoring

Understanding how an urban forest changes over time, such as mortality and survival rates, how quickly trees are growing, and whether plantings outweigh mortality, requires longitudinal data to track individual trees over many years. Forest Service scientists and colleagues provide methods and strategies for urban tree monitoring in two new guides, adapting well-established practices from forest ecology. These guides are intended for arborists, nonprofit urban foresters, landscape planners, and others who manage trees in cities, towns, and suburbs. Tracking change over time in urban forests enables practitioners to understand mortality and survival rates, growth rates, and changes in tree health and population size. The Field Guide offers detailed protocols for long-term data collection, such as tree location, mortality status, crown vigor, and diameter at breast height. A companion Resource Guide offers strategies for designing and implementing effective monitoring projects, including managing field crews and constructing longitudinal databases. The guides were developed collaboratively with urban forestry professionals, representing the co-production of knowledge across research and practice.

New guidelines help cities manage the slow-moving wildfire that is the Emerald Ash Borer invasion

Emerald ash borer (EAB) is like a slow-moving wildfire spreading through urban forests and killing ash trees. City foresters need guidelines that can slow the insect's spread and preserve a community's investment in urban forestry. To meet city foresters' need for practical management guidelines, Northern Research Station scientists developed a model that evaluates EAB surveillance and control strategies with the objective of maximizing the benefits of healthy trees. The model captures the dynamics of ash trees moving through different levels of infestation. Scientists calibrated and validated the model using 7 years of infestation observations in plots in northern Ohio and subsequently used it to develop the following management guidelines for the city of Burnsville, MN: 1) It is critical to apply surveillance immediately to find the infestation and then treat trees with low to moderate levels of infestation and remove highly infested trees; 2) Surveillance and treatment or removal actions should mainly focus on locations where the infestation has started; and 3) If the budget is not sufficient, the planner may need to forego removing highly infested trees in favor of treating low- and mid-level infested trees to save them and prevent new infestations. These guidelines emphasize the importance of surveillance before treatment or removal to maximize benefits from ash trees and reduce management costs.

Synthesis of invasive species research for the U.S. forestry sector

Invasive species are among the most serious threats to native ecosystems. The introduction and establishment of invasive species continues to increase with ever-expanding world trade, and there appears to be no sign of saturation for most taxonomic groups. Over 100 national experts, including 75

Forest Service experts, contributed to synthesizing the latest research on a wide range of natural science and social science fields that explore the ecology, impacts, and practical tools for managing invasive species. Northern Research Station scientists worked with a planning team of seven scientists from other research stations and the Washington Office to help lead a national stakeholder workshop that included experts on a wide range of topics related to invasive species. Stakeholders from nongovernment organizations, academic institutions, professional organizations, private corporations, and state and federal agencies representing public, private, and tribal interests provided input. The report covers species of all taxonomic groups from insects and pathogens, to plants, vertebrates, and aquatic organisms that impact a diversity of habitats in forests, rangelands, and grasslands of the United States. The report presents the latest research on a wide range of natural science and social science fields that explore the ecology, impacts, and practical tools for invasive species management and provides summaries of the most important invasive species and issues impacting all regions of the country. This comprehensive review will be a valuable resource for scholars, policy makers, and natural resource managers and practitioners.

Spatially targeted drone carries biocontrol weevil to hard-to-reach patches of mile-a-minute weed

A tiny weevil (*Rhinoncomimus latipes*) is a specialist biocontrol agent of mile-a-minute weed, a highly invasive annual plant in the United States. Currently this weevil is released by hand where the presence of the weed is readily detected, which is not practical for large infestations and hard-to-reach areas. West Virginia University researchers and a Northern Research Station scientist developed a spatially targeted biocontrol strategy using an unmanned aerial system, or drone, to detect mile-a-minute weed patches

and release the weevil. The team determined the detectability of mile-a-minute weed patches by flying a rotary-wing drone at 15 different altitudes and taking aerial images using natural-color and near infrared sensors. A followup ground survey confirmed of the accuracy of aerial images in locating mile-a-minute weed. The team addressed the second problem, weevil delivery, by developing a new insect-release system that uses 3-D printing to create biodegradable polyvinyl alcohol pods. Results showed that mile-a-minute weed patches were readily detectable on the aerial images at an altitude of approximately 25 meters, and more than 98 percent of weevils successfully escaped from the pods within 24 hours after aerial release. Researchers delivered an aerial detection and deployment method that is reliable and environmentally friendly.

New and improved site index curves developed for Red Spruce

One key factor in restoring red spruce is understanding the site quality of potential restoration sites. To assess site quality, foresters measure tree heights and tree ages to produce site index curves for tree species commonly occurring in the area. Northern Research Station scientists and partners from West Virginia University have developed new site index curves to replace nearly century-old curves to better assess site quality of red spruce habitat. By combining these new site index curves with site specific tree species, climate, and geographic data, the scientists have further refined the estimation of site quality to guide restoration efforts for this important species. With these new site index curves, forest managers can also better estimate growth and yield for future timber production of red spruce. High elevation red spruce in the central Appalachians was historically an important and dominant timber species but is

currently reduced to a fraction of its former range due to excessive logging in the late 1800s and early 1900s.

A tree species' evolutionary history predicts impact of invasive pests

Research by Northern Research Station scientists and their partners presented the first evidence supporting a long-held hypothesis that a tree's evolutionary history is key to its susceptibility to nonnative herbivorous insects. Advancing managers' ability to predict which native trees are most susceptible to which nonnative insects has the potential to be a game-changer in managing risk from invasive species.

For more than a century, scientists have worked with little success to understand why some nonnative insects prove devastating and others harmless. In a study of invasive insects affecting conifer species, a research team that includes scientists from the USDA Forest Service, the U.S. Geological Survey, industry, and universities has turned the problem around by considering the insects' host tree species and how they have evolved rather than focusing solely on the insect. The result is a novel model for assessing the probability that nonnative insects that have not yet arrived in North America will cause widespread mortality of North American conifer species. The study revealed that when host trees in an insect's native range are very closely related or very distantly related to its host trees in the invaded range, there is a low probability of impact. However, when the relatedness of hosts in the native and introduced ranges are intermediate, there is a much higher probability of tree damage and death at the ecosystem scale.

A new model forecasts Emerald Ash Borer invasion across the Nation

From the time that emerald ash borer was first detected near Detroit, MI, nearly 30 years ago, homeowners and communities have had little warning of where and when the insect would spread. A new model developed by a Northern Research Station scientist and his collaborators forecasts emerald ash borer invasion from 2022-2030, creating a critical new tool in protecting ash forests in rural and urban landscapes. Since its accidental introduction to the United States, the emerald ash borer has virtually "burned" across the country, leaving a path of dead trees throughout more than 600 counties as it continues to spread. The loss of ash trees has had economic, social, and ecological impacts for forest managers, homeowners, municipalities, and many others. Predictions of when emerald ash borer is likely to invade new regions would be of critical value for communities in their preparations and response to the invasion. A Northern Research Station scientist and his partners used historical records of emerald ash borer invasion in the United States to fit a mathematical model of this spread from 2022 to 2030. The model is based on statistical analyses linking historical spread of the insect with human population densities, climate, and forest composition. Simulations using this model indicate that the insect will continue to invade new regions of the United States including those contiguous to currently invaded areas, but also more distant locations, such as major population centers of the American West.

New adaptive tools enhance shared stewardship in battling Asian longhorned beetle

Researchers and managers with the USDA Forest Service and Animal and Plant Health Inspection Service (APHIS) are developing new tools that share the activities and results of the cooperative Asian

longhorned beetle (ALB) eradication programs, contributing to a more efficient response and speedier eradication of a potentially devastating nonnative invasive species. The ALB is an invasive insect that threatens some of the most iconic trees in eastern North America, including maples, willows, and poplars. Eradication programs depend on visually surveying individual trees to find infested hosts. In wooded landscapes this can mean surveying millions of individual trees, and multiple surveys may be required to achieve eradication. In 2020, a computer software tool called the "ALB Dynamic Risk v1.0" was expanded to integrate not only the dispersal of the insect, but the history, frequency, timing of surveys, and population growth rates to generate dynamic estimates of risk on the landscape. This tool delivers a consistent method to track the reduction in risk on the landscape as eradication programs progress and to identify parts of the landscape where surveys can provide the greatest progress toward eradication. It also can be adapted as new information becomes available.

Training program becomes foundation of collaborative oak regeneration crusade

In mixed-oak landscapes, regenerating oak is something of a holy grail. An oak regeneration decision-support system developed by Northern Research Station scientists and partners is becoming a foundational tool in efforts to sustain oak forests in Ohio. Developed and sustained by Northern Research Station scientists, SILVAH (Silviculture of Allegheny Hardwoods) is a decision-support system that applies research results to prescribed treatments that improve regeneration outcomes for mixed-oak and Allegheny hardwood forests. Since 2009, 6-week-long SILVAH Oak training workshops have been held at the Vinton Furnace Experimental Forest in Ohio and attended by more than 200 land managers from federal and state agencies, as well as private consulting foresters. The intensive training

includes lectures on oak ecology and silviculture, field tours to demonstrate silviculture practices, collection of SILVAH plot data in the field, and an introduction to the software. Three Northern Research Station scientists led the most recent workshop conducted in fall 2019. The SILVAH system is being used by the Wayne National Forest and the Ohio Department of Natural Resources, Divisions of Forestry and Wildlife, in their efforts to sustain oak forests

Videos make forest management strategies engaging and understandable for landowners

Scientists have conducted research on sustainable forest management at the Penobscot Experimental Forest in Maine for 70 years, generating reams of journal articles and reports that would help a landowner decide whether (and how) to manage their woodlands. Their findings highlight the advantages and disadvantages of different approaches to harvesting, including treatments that maintain forests with simple versus complex structures, few versus many tree species, habitat for early versus late successional species, and maximum short-term versus sustained long-term income. This information is important for landowners of small tracts who are uncertain whether or how they should manage their woodlands, but the types of reports scientists write can be difficult to access and understand. To bridge the divide between experts and non-experts, the USDA Forest Service partnered with the University of Maine, Maine Audubon, and New England Forestry Foundation to produce two videos highlighting research results and introducing concepts of sustainable forestry. These videos include historical and contemporary images from different types of management on the Penobscot Experimental Forest showing how the forest changes over time, as well as interviews with landowners, foresters, and scientists in Maine. Managing for wildlife, carbon, aesthetics, and timber are discussed and common

pitfalls and concerns are explained. More than 4,000 people watched the videos in the first few months they were available online. A companion publication is in development.

Rooted in Research

In 2020, the Northern Research Station launched a new bimonthly publication that synthesizes key science findings and management implications of research conducted by Northern Research Station scientists and collaborators. Rooted in Research is targeted to public land managers in our overall foot print and other individuals who make and influence decisions on managing land. This new publication is designed to bring current research to the most pressing natural resource management issues through succinct, comprehensible science stories, while rewarding station scientists by providing them with a straightforward medium for science delivery. The first two issues described science related to white-tail deer, a perennial obstacle to forest regeneration throughout the Northern Research Station's footprint, and research on adapting red pine forests to changing habitat conditions. The publication will be distributed via Constant Contact, making it a highly accessible source of regional forest science.

Pacific Northwest Research Station

The Pacific Northwest (PNW) Research Station develops and delivers knowledge and innovative technology to improve the health and use of the Nation's forests and rangelands—both public and private. Since 1925, the PNW Research Station has been dedicated to understanding forests and rangelands. We believe that resilient forests are a promise to generations to come—a promise to replenish the air we breathe and the water we drink and use to grow food. Forest trees store carbon from the roots to the tops. Trees supply wood for homes, biomass for fuel, and fiber for paper. From remote mountains to bustling cities, forests provide habitat for fish and wildlife. Wherever they grow, forests are places of beauty, renewal, and solace.

Land managers understand more than ever just how important forests are to people from every walk of life. The PNW Research Station is in the unique position to offer scientific knowledge—built on decades of research—that can be used now to assure future generations enjoy the same benefits from forests that we do today. As part of Research & Development, the station has access to national forests and an experimental forest system that hold the keys to new understanding of forests and rangelands.

The PNW Research Station has strong partnerships with universities, national forests, state agencies, nonprofits, private industry, and other federal agencies. With these partners, we address key questions associated with managing forests, wildlife and fish habitat, recreation, climate change, human health and well-being, and more. We have the honor of bringing science to the table as people make often-difficult choices about managing land.

The PNW Research Station is a leader in the scientific study of natural resources. We generate and communicate impartial knowledge to help people understand and make informed choices about natural resource management and sustainability.

Research in progress

West-side fire research initiative

The PNW Research Station launched the West-Side Fire Research Initiative in 2019 to produce information relevant to fire-related management on landscapes west of the Cascade Range in Oregon and Washington. Wildfires on the west side of the Cascades are becoming more frequent and more intense, with increasing risk to the extensive wildland-urban interface in the area. Scientists, fire managers, and other stakeholders are working to coproduce the science needed to keep people safe and the forests resilient. The group identified 3 priority areas for research: 1) historical and future fire regimes; 2) fuel management; and 3) postfire management. The West-Side Fire Research Initiative will produce actionable science and tools that help managers and responders plan for changing fire regimes

on the west side of the Cascades.

Carbon dynamics research for land and watershed managers

In 2019, the PNW Station launched a carbon research initiative to enhance policy-relevant understanding of carbon flux and carbon accounting, and to fill knowledge gaps about forest carbon dynamics. Forest carbon accounting is notoriously complicated, and uncertainty over the state of science hinders forest management.

The research initiative is addressing unresolved questions of policymakers and other partners. Working groups consisting of researchers, policymakers, and natural resource managers have convened around three questions:

- How do we identify and improve the most appropriate carbon models of the forest sector and all lands?

- What is the state of the current knowledge for green carbon in Pacific States?

- What are the carbon fluxes and social implications of different forest management strategies?

This initiative will deliver tools and information to policymakers and other partners that will help answer questions about forest carbon and how it interacts with other forest management objectives and practices.

PNW Science Delivery

New tool supports informed decisions about the combined effects of wildfire smoke and COVID-19

Degraded air quality from wildfire smoke may exacerbate the respiratory effects of COVID-19, potentially increasing infection rates and worsening infection outcomes. To mitigate the health impacts from the confluence of smoke and COVID-19, researchers with the PNW Research Station, USFS Interagency Wildland Fire Air Quality Research Program, and USFS Fire and Aviation Management created a national Smoke-COVID dashboard to help agency personnel make decisions in situations where both smoke and COVID-19 are factors. The tool tracks and integrates data on COVID-19 cases alongside air quality monitors, fire incidents, satellite fire and smoke detections, and smoke forecasts on a novel platform.

AirNow.gov map makes air quality data available to the public for the first time

Wildfire smoke is the predominant cause of major air quality events in the United States that affect millions of Americans each year, causing significant negative health effects. To enhance the current air

quality monitoring system across the country, researchers from the USDA Forest Service and the Environmental Protection Agency supplemented existing monitoring systems with data from low-cost sensors, dramatically expanding the spatial coverage of air quality monitoring systems the United States.

Integrated climate and genetic monitoring of invasive forest pathogens helps Hawaii protect native trees

Climate change is predicted to exacerbate invasions by forest pathogens and predispose trees to emerging diseases, fire, insects, and other disturbances. Scientists used bioclimatic models to predict current and/or future distribution of brown root rot (*Phellinus noxius*) and myrtle rust (*Austropuccinia psidii*). They verified several genetic groups within both invasive species, and bioclimatic modeling showed that distinct genetic groups pose distinct threats, which must be recognized by regulatory agencies to limit damage and mortality to trees in the tropics and subtropics from these invasive pathogens.

SoCal EcoServe: A tool for visualizing and auantifying impacts of fire on ecosystem services in s outhern California

The tool quantifies and maps pre- and postfire ecosystem services for the shrubland-dominated national forests in southern California. It compiles modeled spatial data relating to water supply and flood control (hydrological runoff, groundwater recharge, and sediment export), carbon storage, biodiversity and

recreation. It provides a repeatable and transparent framework for quantifying the change in ecosystem services and their values associated with damage to natural resources on national forest lands.

Retaining logging debris on site yields multi-year benefits for replanted Douglas-fir

Scotch broom, a nonnative shrub, invades sites following timber harvests in coastal regions of the Pacific Northwest. It outcompetes native vegetation for water and nutrients. Results from a long-term soil productivity study in western Washington indicate that the benefits of retaining logging debris on site can be measured up to 15 years later in the survival and growth of Douglas-fir planted after the previous harvest.

Informing habitat restoration for Coho salmon

Oregon coastal Coho salmon (*Oncorhynchus kisutch*) are listed as threatened under the Endangered Species Act. Forest Service research revealed the importance of connectivity among different types of freshwater habitat for Coho salmon (adult spawning habitat; juvenile summer rearing habitat; juvenile winter refuge habitat). Restoration projects that only focus on individual habitat segments may not lead to watershed-scale improvements. Targeted restoration that fills habitat gaps may be more effective when diversity, location, and proximity of seasonally important habitats already present in a watershed are considered.

Fish density tells the story: large-river stream restoration works

- In the Pacific Northwest, millions of dollars have been spent on stream habitat restoration projects designed to improve rearing conditions for Pacific salmon. New research provides rigorous methods to more conclusively identify fish response to these projects. When applied to the Entiat River system in Washington, the methods show that restoration projects increase the capacity of the river or stream to support fish. This finding has provided sponsors of restoration projects in the Entiat River system with increased confidence in the success of their efforts.

A new mobile app for collecting stream data essential for management

The western Oregon stream FLOW PERmanence (FLOwPER) project is using the latest technology to more accurately characterize headwater streams in western Oregon as seasonal or year-round flows. The presence of year-round water determines the size of riparian buffers that are required by the Northwest Forest Plan, the Oregon Forest Practices Act, and best management practices. This project will help reduce the cost of pre-project planning and monitoring associated with forest management activities.

The FLOwPER project is yielding field data and lidar data that are being used to update the National Hydrographic Dataset, the centralized, multi-agency, stream dataset that forms the foundation for land management with respect to streams. The long-term goal is for FLOwPER to become a nation-wide, multi-agency resource to help inform land management on all federal lands.

Controlling pest outbreaks to enhance the health of western forests

Scientists and national forest managers collaborated on a study to abate outbreaks of the Douglas-fir tussock moth. In the Okanogan-Wenatchee National Forest, the model predictions were directly used to allocate biocontrol efforts to manage moth outbreaks at several sites on the forest. The results largely followed predictions, thus showing the benefit of these models in pest management.

Passive acoustic monitoring effectively detects northern spotted owls and barred owls

Northern spotted owls (*Strix occidentalis caurina*) are listed as threatened under the Endangered Species Act. Populations have been monitored since the mid-1980s by using labor intensive mark–recapture methods that require call-back surveys and using mice to lure owls for capture and leg-band reading. Land managers, conservationists, and researchers have sought alternative methods that yield robust data while being less costly, suitable for multiple species, safer for field crews, and noninvasive for spotted owls.

The results of study that used passive bioacoustics as an alternative survey method demonstrate that it can effectively meet monitoring objectives. These findings are being used to design and inform the transition from mark-recapture to passive bioacoustics as the primary monitoring method for northern spotted owl populations under the Northwest Forest Plan effectiveness monitoring program.

Effects of common management practices on greater sage-grouse synthesized for easy reference

This new resource describes specific characteristics of suitable habitats for greater sage-grouse, a bird that been proposed for listing under the Endangered Species Act and is ranked as imperiled in several western states. The authors summarized the published literature on predominant management activities, including fire, grazing, pesticide and herbicide application, and energy and urban development. The resource also includes a unique comprehensive tabulation of vegetation structure and composition in sage-grouse breeding habitats, summarized by management practice and habitat type, for all states and provinces in the species' range. The new synthesis was downloaded more than 150 times in the first months of its release.

Higher sales prices for single-family homes associated with urban trees in Tampa, Florida

The City of Tampa faces major redevelopment pressure that could directly affect the relationship between urban trees and single-family house prices. Policymakers and developers wanted to know how the presence of trees could affect the value of houses being sold for redevelopment.

Researchers found that, after accounting for the influence of different house and neighborhood characteristics, houses with trees within 500 feet of the lot were associated with higher sales prices. A 1-percent increase in tree cover was associated with an increase in sales price of more than $9,000. The City of Tampa used this information to inform revisions to their tree protection ordinance.

PACIFIC SOUTHWEST RESEARCH STATION

The Pacific Southwest (PSW) Research Station represents FS R&D in the States of California and Hawaii and the U.S.-affiliated Pacific Islands. The region has the lowest, driest desert in the country, the highest elevations within the 48 contiguous States, and the wettest tropical forests. It is home to an abundant diversity of native plants and animals and nearly half of the Nation's threatened and endangered species. PSW scientists are engaged in research across a network of 14 experimental watersheds, ranges and forests and eight research facilities. PSW scientists conduct a broad array of natural resources research to achieve our mission to "develop and communicate science needed to sustain forest ecosystems and their benefits to society." Research is organized into five research units: conservation of biodiversity, ecosystem function and health, fire and fuels, urban ecosystems and social dynamics, as well as Pacific Islands forestry. For more information, visit www.fs.fed.us/psw.

PSW Science Delivery

Plant pathology program

PSW scientists, working with state and university partners, developed a plant pathology program at its Institute of Pacific Islands Forestry (IPIF) to coordinate and implement all aspects of a complex major forest pathogen including detection, evaluation, prevention, resistance, and control programs for such diseases as Rapid ′Ōhi′a Death) This program will create a well-organized science-based system for identifying and addressing new pathogens. Hawaii's climate and role in the importing and exporting of products makes it especially susceptible to harmful forest pathogens. Having a well-organized system in place will minimize the negative ecological impacts and costs that these pathogens can cause.

Field monitoring of urban trees

Field monitoring of urban trees is essential to understanding how urban forests change over time. Two companion reports – the *Urban Tree Monitoring: A Field Guide* and the *Urban Tree Monitoring: A Resource Guide* -- lay the foundation for practitioner-driven long-term studies of tree mortality, growth, and health. The Field Guide gives detailed protocols for how to record a key set of variables, including mortality status, location, trunk diameter measurements, and crown vigor. The resource guide offers a lengthier deep-dive into various considerations for designing and implementing a monitoring program. In addition, five short films, produced in collaboration with Forest Service's Pacific Southwest Region, explain select parts of the field guide and resource guide and, like the guides, are intended for urban forestry professionals such as those working for municipalities, state forestry agencies, local urban greening nonprofit organizations, urban forestry advocacy groups, and contract urban foresters.

Stanislaus National Forest scenario planning project

PSW scientists are working closely with Stanislaus National Forest staff, local collaboratives, and with Alan Ager and his (ForSysX) team on one of only a few serious pilot efforts nationwide to examine use of ForSysX on a specific national forest. The team has identified the 5 objectives that are most important for the local planning area, have set up a team specific to each objective, and have developed a list of data needs to inform the planning around each objective. While there is much work yet to be done, the work completed in FY 2020 has been foundational the success of this scientifically informed scenario planning strategy.

A framework for socio-ecological resilience in the Sierra Nevada

A collaborative of 10 agencies and organizations, the Tahoe Central Sierra Initiative (TCSI), is working to improve landscape resilience in the central Sierra Nevada through a strong scientific foundation, innovation, and action. As part of the scientific foundation, a Framework for Socio-ecological Resilience was recently completed. In the 2.4M acre TCSI landscape, we are demonstrating how the Framework can be used to identify opportunities where future management can be directed to move toward desired conditions across the landscape. The Framework for Resilience and its application in the TCSI landscape provide a valuable model for how assessments and planning across large, regional-scale landscapes can directly inform and support project planning.

Lake Tahoe restoration

Science supports progress: Over the past 4 years in the Lake Tahoe basin, PSW scientists have been leading a science team, working shoulder-to-shoulder with NFS staff and colleagues from various universities to address a fundamental question facing most landscapes, which is “how much of what type of treatments will be most effective in achieving multiple restoration objectives.” The diverse interdisciplinary science team had expertise in forestry, fire, wildlife, smoke, hydrology, and economics. We developed a novel approach to evaluating the performance of five different management scenarios and climate change modeled over nearly 100 years across the 60,000 acre landscape on the west shore of Lake Tahoe that addressed how management could be designed and implemented to accomplish objectives in all six resource areas. The results were used to inform a Landscape Restoration Strategy for the Lake Tahoe west landscape, as well as provide a foundation for developing basin-wide management strategies that can help forest ecosystems adapt to future climate conditions and retain high environmental quality in the watersheds of Lake Tahoe.

Variable density thinning

PSW scientists published work detailing initial results of a study finding that, when followed up with prescribed fire to reduce surface fuel loads, stands treated with ’”high variability” thinning should not only provide greater habitat value to associated animals and plants, but also enhance resilience to drought and wildfire. Many land managers, including the managers from the Stanislaus National Forest where the studies have taken place, eagerly anticipate the additional research on this topic for use in their NEPA analysis and project implementation.

Detecting illegal marijuana grow sites

The USDA FS initiated a program using new high-tech and non-traditional technologies to gain an upper hand on detecting even well-hidden grows. Forest Service R&D partnered with law enforcement and Integral Ecology Research Center (IERC) to develop the Detection and Interdiction of Marijuana to aid Enforcement and Conservation (DIMEC) model to identify grow sites hidden in the forest canopy using deep learning image recognition of high-resolution aerial imagery. The tool can identify grows outside of the growing season allowing for more cost effective and safe remediation of sites before the growers return in the spring.

3rd experimental timber harvest

A long-term partnership between the Pacific Southwest Research Station and the California Department of Forestry and Fire Protection led to the successful implementation of the 3rd experimental timber harvest in the Caspar Creek Experimental Watersheds. The first two experiments at Caspar Creek led to substantial changes in sustainable forest management within the state of California, as well as foundational understanding of forest hydrology and watershed responses to disturbances. With its extensive and intensive scope and its encompassing collaborative approach, the 3rd experiment is positioned to build on the legacy of foundational and applied forest hydrologic research and expand our knowledge about the impacts of forest management for decades to come.

Rocky Mountain Research Station

Rocky Mountain Research Station scientists work in a range of biological, physical and social science fields to promote sustainable management of the Nation's diverse forests and rangelands. The Station develops and delivers scientific knowledge and innovative technologies with a focus on informing policy and land-management decisions. Our researchers work in collaboration with a range of partners, including other agencies, academia, nonprofit groups, and industry. The Rocky Mountain Research Station serves the Forest Service as well as other federal and state agencies, international organizations, Tribes, academia, non-profit groups and the public. Our Science Programs include: Air, Water and Aquatic Environments; the Aldo Leopold Wilderness Research Institute; Fire, Fuel and Smoke; Forest and Woodland Ecosystems; Grassland, Shrubland and Desert Ecosystems; Human Dimensions; Inventory and Monitoring; Science Application and Communication and Wildlife and Terrestrial Ecosystems.

RMRS maintains 14 research laboratories throughout a 12-state territory encompassing the Great Basin, Southwest, Rocky Mountains, and parts of the Great Plains. RMRS administers and conducts ecological

research on 14 experimental forests, ranges and watersheds over the long-term. Some of this research dates back over a century and offers invaluable insight into how forests change over time, particularly as we face a changing climate and new disturbance regimes. We also oversee activities on several hundred research natural areas, a network of ecosystems set aside to conserve biological diversity.

Station-wide science delivery and technology transfer

The Rocky Mountain Research Station public-facing website uses a modern Drupal-based platform which has provided a template for modernization for Research & Development. This year our website had over 900,000 pageviews (a 20% increase from last FY). The Rocky Mountain Research Station is actively engaged in the R&D web modernization effort, which will greatly improve efficiency of IT resources, unify R&D, and allow R&D web content to align with USDA web requirements.

The Rocky Mountain Research Station *Science You Can Use* (SYCU) publication continues to be highly regarded and sought after by land managers, congressional staff and other scientists. This year we continued to expand our reach and impact. We produced 6 *SYCU Bulletins* and 17 *SYCU (in 5 minutes).* We also launched a highly successful *Science You Can Use* webinar series in the spring to take advantage of the maximized telework stance. These short, interactive land manager-focused webinars enjoyed excellent participation (1,400 attendees at live webinars, 5,351 follow-up webinar

pageviews). We also created and shared monthly growing season rangeland fuels webcasts, which were particularly timely given intense drought conditions in southwest rangelands.

The Science You Can Use publications synthesize research conducted by station scientists and collaborators and deliver key science findings and management implications to people who make and influence decisions about managing land and natural resources.

RMRS teaches at NAFRI

Several Rocky Mountain Research Station scientists taught lessons in two separate weeklong trainings at the National Advanced Fire and Resource Institute (NAFRI) in Tucson, Arizona in January 2020. Both courses use lectures, case studies, a field trip, and structured interaction among and between students and faculty to deliver science and create a shared learning experience. The first class, Advanced Fire Effects, also known as RX510, supports the integration of fire effects knowledge into land management programs. This course, for wildfire operations personnel and fire practitioners, emphasizes design, implementation, and monitoring of planned fire treatments over space and time. The second class, Fire in Ecosystem Management, or M580, enhances the knowledge and understanding of fire management and fire ecology. This course targets resource managers, wildland fire planning personnel, and line officers to become actively engaged in ecosystem management across the landscape. RMRS scientists with the National Fire Decision Support Center taught students about Fire Economics and Ecosystem Services. Faculty cadres for both training courses included scientists and managers from several universities and other federal and state agencies. NAFRI is a national training center dedicated to the diverse interagency fire, fuels, resource, and incident management community in developing and enhancing learning experiences. The Institute assists in the creation of innovative solutions that concern fire and all-hazards management. You can find more information on NAFRI and their available courses on their website.

Integrating more social science into public engagement and National Forest planning processes

Social science recently developed at the Aldo Leopold Wilderness Research Institute, in collaboration with the University of Montana, has focused on providing the National Forest planning community with scientifically robust tools for integrating diverse values and perspectives into the planning process. These tools, such as the recently published social vulnerability protocol (https://www.fs.usda.gov/treesearch/pubs/59038), have been communicated to federal land managers and planners through a "Science You Can Use" webinar. In addition, Aldo Leopold Wilderness Research Institute scientist Chris Armatas recently presented, as an invited guest, to The Wilderness Society about social science methods for application in broad-scale planning processes. While the federal land management agencies generally lead the planning process and the corresponding public engagement, participation of non-federal entities (e.g., NGOs, interested citizens) is critical to successful planning efforts (e.g., forest plan revision, comprehensive river management planning). As the Forest Service continues to pursue shared stewardship, communication between the agencies and non-agency stakeholders will be critical. Social science can help such communication.

RMRS scientist Chris Armatas works with National Forest System collaborators at Forest Plan Revision meeting

Wildfire risk to communities

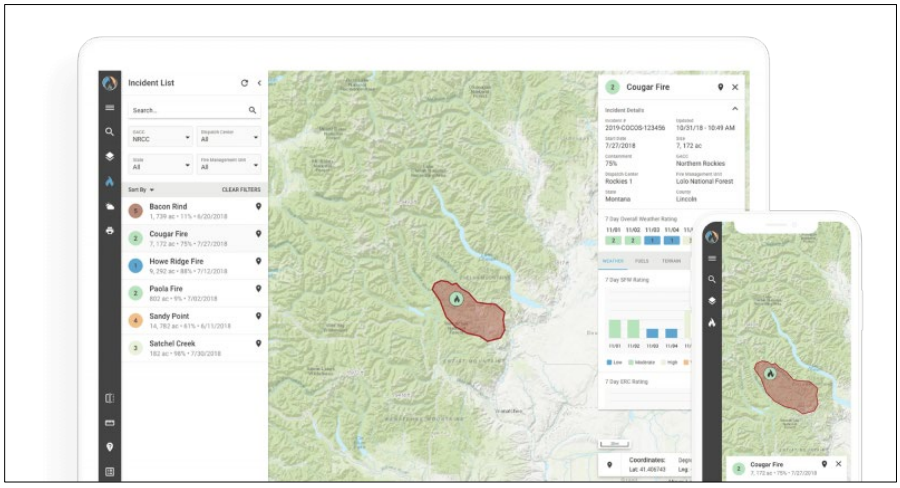
Wildfire Risk to Communities is a joint partnership effort between USDA Forest Service Washington Office Fire and Aviation, Rocky Mountain Research Station Fire Modeling Institute, Pyrologix (a geospatial analysis company headquartered in Missoula, MT), and Headwaters Economics (a research nonprofit based in Bozeman, MT). This program was directed by Congress under the 2018 Omnibus Act to help communities understand, manage, and mitigate wildfire risk. Spatial products are geared towards several groups including elected officials, land use planers, fire collaborative, and fire marshals. Products include maps showing wildfire likelihood, home risk, and wildfire source areas. Maps are available at www.wildfirerisk.org. Additional information about this work can be found here: https://www.fs.usda.gov/rmrs/science-spotlights/wildfire-risk-communities

WildfireSAFE

WildfireSAFE is a new app developed by Dr. Matt Jolly of the Rocky Mountain Research Station Fire, Fuels, and Smoke Science Program that is designed to help fire managers understand fire hazards and make informed decisions concerning wildfire incident management and resource prioritization. WildfireSAFE integrates real-time data from multiple data sources, like drought conditions from the U.S. Drought Monitor and satellite-derived vegetation conditions, into a single, user-friendly web platform. Within minutes of a reported wildfire, fire managers can open the app and zoom in on the wildfire's location. They can then view weather analysis for any active incident, compare active incidents within an area of interest, and capture observations about fire behavior. The app also automatically analyzes the fuels, terrain conditions, and values at risk in the surrounding area. WildfireSAFE is available on desktops, tablets, and mobile devices, and is designed to be used by the

Forest Service as well as private industry, local and state firefighting organizations, and the general public. The app is already in use in the field, supporting the interagency fire community in the planning, response, and recovery phases of wildfire management. More information can be found at https://wildfiresafe.technosylva.com/

Read more about WildfireSAFE here: https://www.fs.usda.gov/rmrs/science-spotlights/wildfiresafe-real-time-data-improve-wildfire-management



In the WildfireSAFE desktop and mobile apps, users can navigate to a wildfire and find real-time data that includes seven-day weather fire danger forecasts, terrain, and drought conditions.

Lessons Learned after 20+ years of fuel treatments in a ponderosa pine forest

The Lick Creek Demonstration/Research Forest studies were established in 1991 in western Montana to evaluate tradeoffs among alternative forest cutting (i.e., thinning and retention shelterwood) and burning strategies aimed at reducing fuels and moderating forest fire behavior while restoring historical stand structures and species compositions. These types of long-term studies are critical for forest managers across jurisdictions. The experiment consists of two independent studies of thinning and retention shelterwood cuttings, with and without prescribed burning treatments. Throughout the 23 years since the treatments, numerous effects on the forest ecosystem have been studied, including fuels, forest structure and composition, understory species responses, tree physiology, resistance to bark beetles, carbon storage, and fire hazard. Permanent photo points established in each study also visually document forest and fuel change over time. Our findings are actively being shared with land managers via a Joint Fire Science Program brief and an upcoming Science You Can Use. An important finding of this work is that fuel reduction and restoration treatments are most successful with a combination of cutting and burning strategies. However, fuel treatments in low-elevation dry forests will likely not remain effective for much longer than historical mean fire return intervals, so maintenance/re-entry treatments are needed. Read this research spotlight to learn more: https://www.fs.usda.gov/rmrs/science-spotlights/lick-creek-lessons-learned-after-20-years-fuel-treatments-ponderosa-pine-forest

FIA specialists update REDDcompass forest monitoring tool

Forest Inventory and Analysis (FIA) specialists from the Rocky Mountain Research Station and the Northern Research Station served as co-authors of the multinational Methods and Guidance Documentation that forms the basis of the newly updated REDDcompass forest monitoring tool.

Numerous countries use REDDcompass as a road map for developing national-scale forest monitoring systems that are compliant with guidance issued by the Intergovernmental Panel on Climate Change (IPCC). The updated tool offers expanded guidance on ground data, including national forest inventories, statistical estimation techniques, and integration of ground data with remote sensing. The USDA Forest Service supported the contributions of several current and former FIA specialists via the interagency SilvaCarbon program, which addresses the USDA Forest Service strategic goal of applying knowledge globally. REDDcompass is hosted by the Global Forest Observations Initiative, under the umbrella of the United Nations Food and Agriculture Organization.

New landscape change monitoring system

The Landscape Change Monitoring System (LCMS) is an important new dataset and tool that allows the user to create landscape-scale historical disturbance maps. LCMS combines satellite imagery with other monitoring data to produce annual maps showing change (vegetation loss and vegetation gain), land cover, and land use, generating a "best-available" map covering multiple disturbance processes and diverse cover types. The data and tool can assist with forest plan revision, updating existing vegetation maps, assessing landscape conditions, supporting post-fire recovery, meeting broad-scale monitoring requirements, and other tasks. Staff can receive training in using LCMS through the USDA Forest Service Geospatial Technology and Applications Center (GTAC), and the tool and a tutorial are available to the general public through a web-based application. LCMS was shared widely with land managers as a recent Science You Can Use (in 5 minutes).

The Landscape Change Monitoring System helps understand and visualize landscape-level changes over time.

New Conversion of FIA data simplifies use in Forest Vegetation Simulator

Using combined analytical power, a breakthrough in data translation and conversion combines the power of two forestry analysis tools in answering forestry management questions. Together, the Forest Inventory and Analysis (FIA) database and the Forest Vegetation Simulator (FVS) comprise a powerful toolset that allows managers and researchers to assess the status and trends of a wide variety of forest types over large areas. Users can also evaluate the outcomes of possible future management scenarios. The FIA program collects data on forest characteristics in all forest types and across all ownerships in the United States (non-forest locations in many regions are also visited to quantify rates of land use change). The FIA database represents the largest and most diverse forest database in the world.

FVS is a computer program used by a variety of managers and scientists to project today's forest conditions into the future. For almost two decades there has been increasing demand to use FIA data in FVS but translating the data from one format to the other has been a difficult task. Previous translations were either incomplete or contained errors, so the combination of the data and program could not be used to its full potential. John Shaw, a Rocky Mountain Research Station Research Forester and analyst

for the FIA Program, has played a key role in developing a new translation process, which converted FIA data from over 1 million plot visits into a format that is read directly by the FVS. This new datamart URL is easily accessible at https://apps.fs.usda.gov/fia/datamart/datamart.html

Synthesis tools for forest planning

A new publication by RMRS scientist Kas Dumroese and his collaborators, called Northeastern California Plateaus Bioregion Science Synthesis (RMRS-GTR-409), is the result of a specific request made by local governments to the Forest Service Pacific Southwest Regional Forester. The synthesis has a Northeastern California focus on sagebrush rangeland, dry pine forestland, juniper forests, habitat and wildlife, society, and response to disturbances, particularly those related to climate. The Lassen and Modoc National Forests are located where the Great Basin, the Sierra Nevada, and the Southern Cascades meet. For forest plan revisions, other science syntheses have focused on the Cascades and the Sierra Nevada and are relevant to the Lassen and Modoc National Forests but do not cover some important ecosystems and topics. The newly published RMRS-GTR-409 resulted from a specific request made to the Pacific Southwest Regional Forester by local governments to cover ecosystems and topics not discussed in the other two syntheses. The scope was the direct result of public involvement, and includes information on dry pine forestland, sagebrush rangeland, habitat and wildlife, society, and response to disturbances, particularly climate. Together, these three syntheses complete the scientific picture that will inform forest plan revisions on the Lassen and Modoc, as well as other National Forests in the Western United States with similar habitats and help meet the 2012 planning rule requirement for using the best available science. Read more about this science in this Science You Can (in 5 minutes)

which was shared widely with land managers: New California Plateaus Science Synthesis: Science Supporting Dry Forest and Rangeland Planning.

This synthesis includes a section on rangeland, covering topics such as public perceptions; interactions of grazing, climate change and carbon storage; rangeland restoration; managing threats to rangeland; and biological soil crusts.

Adapting the common garden tool to guide forb seed transfer

Common gardens are a tool for examining variation in performance across the range of a plant species and are the best way to develop seed transfer guidance for restoration. The Great Basin Native Plant Project, a USDA Forest Service- and Bureau of Land Management-led partnership, is developing seed transfer guidance for native forbs, important components of wildlife habitat but underutilized in restoration efforts. We selected three common Great Basin species considered important for management needs. Seedlings from many populations of each species were planted into six common garden sites across Idaho, Nevada, Oregon, and Utah, where their performance in each environment is monitored. Many partners coordinate

resource acquisition, land use and garden monitoring, including: The Nature Conservancy, Eastern Nevada Landscape Coalition, University of Nevada Reno, Utah State University, and many USDA Forest Service and Bureau of Land Management resource managers. The end-product will be a spatially explicit restoration tool that will inform the appropriate selection of seed for restoration projects and will be useful for public and private landowners, the seed industry and others interested in restoring range landscapes. Future goals include incorporating additional species and creating a streamlined approach to seed transfer development. For more information, see our Science Spotlight.

Climate Smart Restoration Tool: planning restoration now and for the future

Decades of genetic research have shown that environment, in particular climate, strongly affects plant fitness and the geographic distance seed can be moved from its collection source. Are local populations genetically positioned to mitigate climate change? If not, where do seeds/seedlings need to be moved to maintain species fitness? The Rocky Mountain Research Station collaborated with the U.S. Deptarment of Agriculture, the Bureau of Land Management, the Pacific Northwest Research Station, Utah Department of Natural Resources and Conservation Biology Institute to develop the Climate Smart Restoration Tool (CSRT), a web-based platform that maps seed transfer areas, capitalizes on these genetic models, ensemble climate change models and species niche models to map current or future seed transfer areas for individual species. Users simply choose the timeframe (contemporary or future projections), location and species, and the website tool calculates and maps areas suitable for seed transfer. This tool applies to all western states, current species and restoration needs are most applicable

to Idaho, Nevada and Utah. Read more about genetic models for big sagebrush and bluebunch wheatgrass.

North American nursery technology webinar series

A Nursery Technology Webinar Series was developed for forest and conservation nurseries throughout Idaho and North America. The series, that was initiated, planned, and led by Rocky Mountain Research Station Research Plant Physiologist Jeremiah Pinto, aims at bringing nursery technology information to managers, end-users, growers, and technicians in the absence of in-person meetings due to the COVID-19 pandemic. Read more about how Rocky Mountain Research Station scientists support public and private nurseries in The intersection of science and technology transfer: Reforestation, Nurseries, and Genetic Resources Team. Five U.S. and Canadian nursery associations, including one managed by the University of Idaho, are participating. Registrations topped 500 and include participants from around the world.

School teachers sow paintbrush and yucca seeds in the new Cultural Plant Propagation Center at the Moencopi Day School in Tuba City, AZ.

Pinyon and juniper science synthesis

Pinyon and juniper woodlands occupy over 70,000 square miles of the Great Basin and Colorado Plateau including parts of Idaho, Nevada, Utah, and other western states. Changes occurring in these ecosystems—both expansion and contraction—are of concern to land managers and communities. A new, comprehensive science synthesis provides the best-available information on the distribution, history, ecology, hydrology, and management of these woodlands. The synthesis identifies management strategies to meet local needs and will be of interest to managers, researchers, and the public. Coauthors are from Oregon State University, the Rocky Mountain Research Station, the Bureau of Land Management, and the USDA Agricultural Research Service Read more in: The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Northern Colorado Plateau of the western United States.

A semiochemical tool for manipulating tamarisk control

Saltcedar (*Tamarix* spp.), an aggressively invasive Eurasian tree, is a dominant and widespread woody riparian species in the southwestern U.S. While saltcedar's extensive displacement of native trees is detrimental, it is now used as habitat by many species, including the endangered southwestern willow flycatcher (*Empidonax traillii extemus*). The leaf beetle *Diorhabda carinulata* feeds on saltcedar foliage, so it can be used as a control agent to manage saltcedar invasion. This biocontrol can be made more effective with semiochemicals (smells), which can attract or repel beetles. A "push-pul"' manipulation of the insect – using both repellent and attractant chemicals in tandem – can be used to control unwanted stands of saltcedar, while protecting stands being used by wildlife. To help land managers charged with controlling saltcedar across the west, Rocky Mountain Research Station scientist Sharlene Sing partnered with Montana State University to develop and produce time-release lures used to manipulate the spatial distribution of the tamarisk biocontrol beetle *Diorhabda carinulata* by enhancing its aggregation and intensifying saltcedar defoliation. This semiochemical treatment intensifies *D. carinulata* feeding on saltcedar, causing an increase in foliar dieback and decrease in live canopy. 4-oxo-(E)-2-hexenal produced by saltcedar plants under heavy defoliation by *D. carinulata* has a repellent effect on aggregation of reproductive adults and could be potentially deployed in a timed-release bait to repel beetles in habitats used by endangered bird species. Read more at https://www.fs.usda.gov/rmrs/science-spotlights/scent-success-beetle-smells-can-help-protect-environment-weeds

Releasing Diorhabda carinulata in eastern Montana. (Photo by Megan L. Hofland, Montana State University)

A new yellow toadflax biocontrol agent

Rhinusa pilosa, a stem-galling weevil that attacks invasive yellow toadflax (*Linaria vulgaris*), was recently approved for field release in the United States.. This highly promising biological control agent is currently being propagated only at the Rocky Mountain Research Station Bozeman (MT) Forestry Sciences Laboratory for distribution to land managers working in yellow toadflax infested areas

throughout the country. The weevil demonstrated 75% reduction in below-ground toadflax biomass was reported in plants galled by *R. pilosa* compared to control plants. This finding is particularly relevant because it indicates that galling might not only compromise the spread of *L. vulgaris* by limiting rhizomatous, clonal stem growth, but also probably reduces multiyear persistence and overwintering survival of the weed. Galled plants were 55% shorter and produced fewer shoots than control plants. Gall tissue represented 40% of aboveground biomass of treated plants, with non-gall mean dry above-ground biomass for control plants. Galling also significantly reduced the potential for sexual propagation of yellow toadflax, with the proportion of flowering stems much lower in treatment vs. control plants, and flowering either fully suppressed or delayed in galled plants. Read more at https://www.fs.fed.us/rm/pubs_journals/2018/rmrs_2018_tosevski_i001.pdf

Transferring outcomes of the Great Plains Grassland Summit

The Rocky Mountain Research Station, along with other science and management collaborators, convened a summit of over 200 participants and more than 60 organizations from state and federal agencies, NGOs, industry, and private landowners to better understand stressors and resource demands throughout the Great Plains and how to manage them. In addition, the summit explored collaborative processes for generating new knowledge and for involving producers, conservationists, scientists, and other stakeholders in management decisions. Posters and presentations from the Summit are available here. One of the summit outcomes was a published synthesis of current knowledge based on stakeholder input on key issues facing the Great Plains, viewed here: Management opportunities and research priorities for Great Plains grasslands. Another result is a special edition of articles by plenary speakers in

the journal *Rangeland Ecology and Management*, some of which have already appeared online including: Managing invasive plants on Great Plains grasslands**;** Energy development and production in the Great Plains: Implications and mitigation opportunities**;** An assessment of production trends on the Great Plains from 1984 to 2017; and Pollinators of the Great Plains.

Guide to restoring landscapes with western forbs

The Rocky Mountain Research Station, in partnership with the Bureau of Land Management and Great Basin Fire Science Exchange, has prepared an online book, *Western Forbs: Biology, Ecology, and Use in Restoration*, which synthesizes and summarizes research, particularly information and practical experience gained over the last two decades on native forb species occurring in the Great Basin (Nevada, Utah, and Idaho) and beyond. The book aids seed collectors, seed growers, nurseries, landowners, restoration contractors, land managers, and researchers as they increase the supply and use of native forbs and seek knowledge about appropriate species for restoring Great Basin landscapes. The book is comprised of individual chapters that summarize an individual species' biology, ecology, seed technology, and use in restoration. There are 24 species-focused chapters completed, and new species chapters are added as they are completed. The book is available on the Great Basin Fire Science Exchange website (https://greatbasinfirescience.org/western-forbs-restoration/) and individual chapters are available in TreeSearch.

New PhenoMap tool

Monitoring vegetation phenology in New Mexico is important for managers who need phenological information to time activities such as grazing, ecological restoration plantings, control of invasive species, seed collection, and wildlife monitoring. However, tools to deliver timely seasonal development have been limited either spatially or temporally. Rocky Mountain Research Station and Pacific Northwest Research Station scientists developed another option called PhenoMap. This is a weekly assessment of land surface "greenness" across the continental United States that employs the Normalized Differential Vegetation Index (NDVI) derived from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data. We found that PhenoMap effectively tracks phenology on grasslands, shrublands, deciduous broadleaf, and mixed forests. Partners include Northern Arizona University, the University of New Hampshire, and the United States Geological Survey. Read more in: Monitoring land surface phenology in near real time by using PhenoMap.

Ecological resilience approaches to improve management strategies

Information on ecological resilience can greatly increase the ability to prioritize management activities in those locations where they provide conservation and restoration benefits. Recent research shows that an understanding of an ecosystem's environmental characteristics and its response to disturbance can be used to assess its resilience and risk of ecological threshold crossings. Newly developed approaches that allow managers to evaluate resilience at the scales needed for management and to determine effective management strategies were recently compiled in an e-book in the journal *Frontiers in Ecology and*

Evolution. Regional collaborators are the Rocky Mountain Research Station, the Pacific Northwest Research Station, the United States Geological Survey, the Natural Resources Conservation Service and universities, and state agencies. Sagebrush rangelands in Idaho, Nevada, Utah and other western states are the focus of several articles. Read more in: Operationalizing the concepts of resilience and resistance for managing ecosystems and species at risk.

FireCLIME Tool for assessing ecosystem vulnerability to wildfire and climate change

Fire-climate interactions are complex and mediated by climate effects on vegetation productivity and resulting fuel loads, fuel conditions, and environmental conditions at the time and place of ignition. As part of a larger Joint Fire Science Program project, Rocky Mountain Research Station scientist Dr. Megan Friggens developed the FireCLIME Vulnerability Assessment tool, which scores ecosystems based on current and future expected climate-fire-vegetation relationships as they relate to user inputs about desired future conditions. This tool provides inference on the mechanisms driving vulnerability and which management strategies may be most effective for reducing risk under changing climate conditions. Currently, the FireCLIME tool is in use to assess landscapes on the Santa Fe National Forest and Lincoln National Forest in New Mexico, and the Bighorn National Forest in Wyoming. Read more: https://www.fs.usda.gov/rmrs/publications/user-guide-fireclime-vulnerability-assessment-va-tool-rapid-and-flexible-system and https://www.fs.usda.gov/rmrs/projects/identifying-vulnerability-southwestern-landscapes-changes-climate-and-wildfire-regimes

Prescribed fire in the Southwestern U.S.

(Photo by Rachel Loehmen, USGS)

Suitability maps for western yellow billed cuckoo woodlands

Riparian forests support a disproportionate amount of biodiversity within the southwestern U.S. Climate change and other disturbances are negatively impacting riparian habitats and the species that rely upon them. The western Yellow-billed Cuckoo (wYBCU), listed as threatened under the Endangered Species Act, has declined due to loss and fragmentation of riparian habitats. Arizona is thought to support the largest population of wYBCU. Rocky Mountain Research Station research ecologist Megan Friggens partnered with Tucson Audubon to provide species habitat suitability models for the entire state of Arizona to provide better information on where wYBCU may exist within the state and where these birds might persist under changing climate conditions. For more information: https://www.fs.usda.gov/rmrs/science-spotlights/modeling-western-yellow-billed-cuckoo-suitable-habitat-arizona-over-next-century

Yellow-billed Cuckoo from the Grand Canyon. (Picture courtesy of National Park Service.)

New ST-Sim Tool helps managers forecast future rangeland conditions

Rocky Mountain Research Station scientists Paulette Ford and Matt Reeves applied a software-based ecological simulation tool called ST-Sim, short for state-and-transition simulation model, to ask landscape-level "what-if" questions focused on Southwestern rangelands. Using ST-Sim, they projected a variety of conditions, including vegetative state transitions, net primary production, drought likelihood, and forage use and grazing targets. One prediction was that, in grazing areas, drier conditions may quickly cause perennial grass cover to be replaced by weedy annual and sparse grasses. Another prediction was that forage grazing targets for some ecological systems would drop significantly below 35 percent of historic annual production. Based on ST-Sim models, the scientists found that increased

drought in the Southwest Region may lead to shrub expansion and transitions between vegetative states, particularly without grazing adjustments. They also determined that ST-Sim can be used to prioritize sites and vegetation types that are candidates for restoration or resilience-building management regimes. Download links, tutorials, and resources at https://www.fs.usda.gov/rmrs/sites/default/files/documents/sycu_tools_ST_Sim_02112020_Final.pdf

Understanding tools that benefit pollinators of the Great Plains

We describe the state of knowledge about responses of pollinators and their foraging and nesting resources to historical natural disturbances and new stressors in the Great Plains. In addition, we also provide information about pollinator management and research needs to guide efforts to sustain pollinators and, by extension, flowering vegetation and other ecosystem services. Although pollinator responses varied, pollinator specialists of disturbance-sensitive plants tended to decline in response to disturbance. Management with grazing and fire overall may benefit pollinators of grasslands. Habitat management and restoration can reduce effects of stressors and augment floral and nesting resources for pollinators. Partners include South Dakota State University, Oregon State University and others. *https://www.fs.usda.gov/rmrs/publications/pollinators-great-plains-disturbances-stressors-management-and-research-needs*

Using drone technology to census rare plants

Rocky Mountain Research Station scientists partnered with Utah Valley University, Utah Division of Natural Resources, The Nature Conservancy's White Dome Nature Preserve, the Bureau of Land Management and the United States Fish and Wildlife Service to determine population status of dwarf bear-poppy (*Arctomecon humilis*), which grows only on barren gypsum soils close to a rapidly expanding urban area, St. George, Utah. Key findings of this work include: Dwarf bear-poppy, and likely other rare plant species with distinctive morphology and color that are found in simple plant communities of open habitats, can successfully be censused using drone imagery; Census maps can be combined with habitat classification to examine fine-scale habitat requirements; Drone-based census can provide managers with distribution data over the entire species range, permitting them to better prioritize management activities; and Drone imagery at higher resolution can also be used to carry out yearly monitoring with an image acquisition protocol that will be economical and user-friendly, so that managers will potentially be able to carry out these activities without expert assistance. Similar technological approaches were more recently applied to census and stabilize populations of the endangered Holmgren's Milkvetch (*Astragalus holmgreniorum*). Read more in Using drone imagery to census a rare desert plant and Saving Holmgren's Milkvetch: A New Approach for Imperiled Species Management

During a 2-year period, the Rocky Mountain Research Station Shrub Sciences Laboratory in Provo, Utah, produced about 45,000 Holmgren's milkvetch seeds for introduction studies.

Guide to restoring landscapes with western forbs

The Rocky Mountain Research Station, in partnership with the Bureau of Land Management and Great Basin Fire Science Exchange, has prepared an online book, *Western Forbs: Biology, Ecology, and Use in Restoration*, which synthesizes and summarizes research, particularly information and practical experience gained over the last two decades on native forb species occurring in the Great Basin (Nevada, Utah, and Idaho) and beyond. The book aids seed collectors, seed growers, nurseries, landowners, restoration contractors, land managers, and researchers as they increase the supply and use of native forbs and seek knowledge about appropriate species for restoring Great Basin landscapes. The book is comprised of individual chapters that summarize an individual species' biology, ecology, seed technology, and use in restoration. There are 24 species-focused chapters completed, and new species chapters are added as they are completed. The team is working to ensure knowledge transfer and broad

distribution of the book such as by posting it on the Great Basin Fire Science Exchange website, a site widely accessed by land managers (https://greatbasinfirescience.org/western-forbs-restoration/) and posting individual chapters to TreeSearch.

Ensuring future seed availability for restoring the Nation's lands

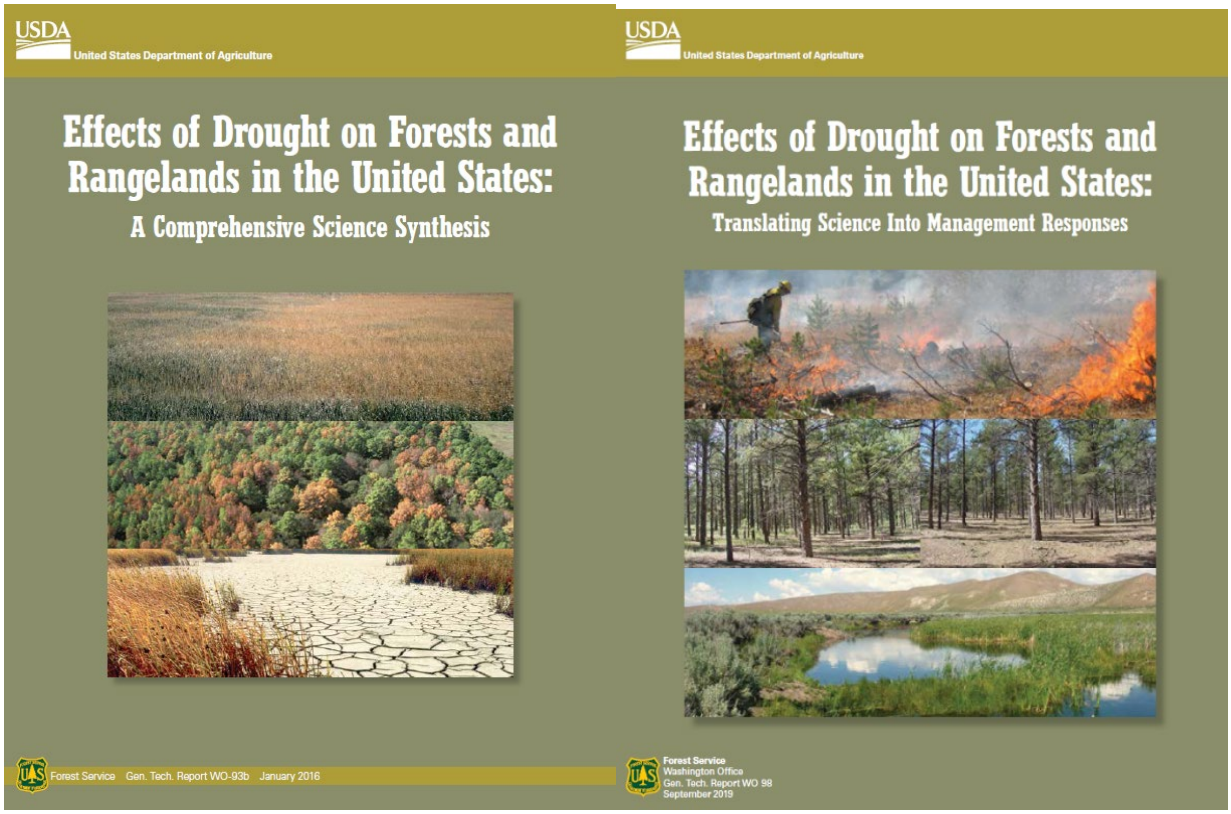
The Rocky Mountain Research Station partnered with the University of Nevada, Reno, the Bureau of Land Management, Chicago Botanic Garden, and state agencies to assess seed collections to ensure they will support current and future needs. The Seeds of Success (SOS) is a national seed collection program led by the BLM that started in 2000. The team performed an analysis of the strengths, weaknesses, opportunities, and threats for the SOS program. Assessment of SOS collections shows that SOS has collected seed from over 24,400 native plant populations from ~5600 taxa from Utah and many other states. Over 10,000 seed collections have been shared for restoration and research use. Fire was identified as a significant risk to previously collected populations of native plants, with 3.5% of georeferenced collection sites having burned since collection. Frequency of burning of collection populations increased dramatically since SOS started collecting seed, shifting from ~29 populations to ~48 burning each year starting in 2011. Read more in Seeds as an investment in the future of US lands.

Adapting to drought: guidance for managers

Much of the United States is projected to experience a higher frequency of severe droughts and longer dry periods as a result of a warming climate. Also, warmer temperatures will interact with drought to exacerbate moisture limitation and water stress. Secondary impacts of drought, such as more frequent and larger wildfires and large-scale insect outbreaks, may have even greater impacts (magnitude and spatial extent) than direct drought effects. Hydrological drought is a major concern in areas dependent on reliable flows of surface water for aquatic species and habitats, groundwater recharge, and drinking water supply. However, drought impacts vary regionally, depending on local climate regimes, land use, and other factors. Drought poses major management challenges to resource practitioners and can have substantial impacts on the economy at local and regional scales.

U.S. Forest Service Research and Development published GTR-WO-98: Effects of drought on forests and rangelands in the United States: A comprehensive science synthesis and translating science into management responses, an important publication with wide manager distribution. This General Technical Report summarizes specific drought issues and region-specific management options for increasing resilience to drought for Alaska and the Pacific Northwest, California, Hawai‘i and U.S. Affiliated Pacific Islands, Interior West, Great Plains, Northeast and Midwest, and Southeast regions. The report builds on a recent state-of-science synthesis on the effects of drought on forests and rangelands of the United States (GTR WO-93b, 2016), and provides important guidance for evaluating management options to minimize drought impacts. The report emphasizes that optimal responses can be developed by integrating existing policies and practices with new information and by timely reporting of current conditions. If drought-informed practices are institutionalized as part of agency operations, then

planning and management will be more effective, and “crisis management” in response to drought can be avoided. RMRS scientists were co-editors of this GTR and co-authors on chapters in this GTR.



GTR-WO-98: Effects of drought on forests and rangelands in the United States: A comprehensive science synthesis and translating science into management responses

Skid-trails from post-fire salvage logging contribute to hillslope erosion

The extent and degree of the soil and vegetation disturbance by wildfire, fire suppression activities, and post-fire management can have long-lasting ecological implications for hydrologic and biological

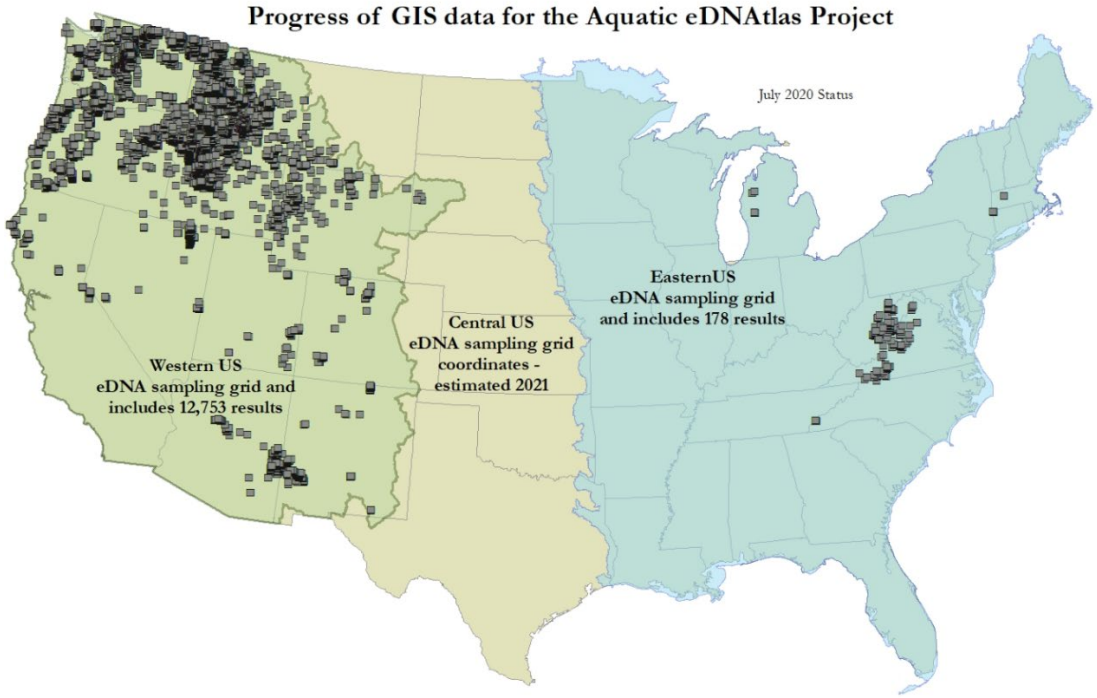
processes. Extended wildfire seasons in the Western U.S. emphasize the need for better understanding of both wildfire impacts and post-fire management on hillslope erosion and watershed responses such as flooding, sediment yield, and debris flows.

Following the 2015 North Star Fire in eastern Washington, Rocky Mountain Research Station researchers used a novel approach to assess impacts of post-fire salvage logging on spatial patterns of hillslope erosion by combining field experiments and remotely sensed imagery. The North Star Fire was part of the Okanogan Complex Fires that burned 209,000 ha — 91,000 ha of which were on the Colville Federation Tribal Reservation and covered nearly 20% of its land base. WorldView-2 satellite imagery was used to relate ground cover and erodible bare soil to measured hillslope erosion using multi-temporal Normalized Differenced Vegetation Index (NDVI) values. Rocky Mountain Research Station researchers found management-relevant impacts when they quantified the influence of skid trails, established during post-fire salvage logging operations, on hillslope erosion. Their results showed that skid trails produced significantly more sediment than either slash treated skid trails or controls with a simulated rill erosion experiment. Similarly, under natural rainfall conditions, sediment yield from hillslope silt fence plots was significantly greater for the skid trail than either the slash treated skid trail or controls. The researchers found that logging slash, applied at a rate to achieve >60% mean ground cover, was an effective treatment to reduce post-salvage runoff and soil erosion and provided recommendations on implementing this practice. Also, significant relationships among NDVI, ground cover, and sediment values suggest that NDVI may help managers evaluate ground cover and erosion potential remotely after disturbances such as a wildfire or salvage logging. Read more here: https://doi.org/10.1002/hyp.13882

The Aquatic eDNA Atlas: mapping occurrence of aquatic biota

Effective conservation of freshwater biota during times of rapid climate change, nonnative species invasions, and habitat loss requires precise information about species distributions across broad areas to guide decision-making. Environmental DNA (eDNA) sampling of aquatic environments offers a reliable, cost-effective, and sensitive means of determining species presence if samples are collected following standardized field protocols and analyzed using rigorously designed eDNA assays. Innovative eDNA sampling is being rapidly adopted to address questions about the distribution of species in headwater streams (e.g. boreal toads), the success of nonnative aquatic species removals (e.g., brown trout removal in native trout stream segments), and the range-wide patterns of occupancy by at-risk species, such as bull trout. To foster these efforts, RMRS scientists at the National Genomics Center for Wildlife and Fish Conservation (NGC) and a group of stream scientists based in Boise, ID partnered with dozens of natural resource organizations throughout North America to provide technical assistance in the form of eDNA assay development and field sampling designs for fish, amphibians, crustaceans, mussels, mammals, and birds (https://www.fs.fed.us/rm/boise/AWAE/projects/eDNAtlas). Samples are collected at thousands of sites annually through those partnerships, which has created a large database that is rapidly growing in geographic extent and species diversity. To facilitate access to this database in spatially-explicit formats that maximize the use and sharing of eDNA sampling results, as well as the efficient collection of new samples, the National Fish Wildlife Foundation commissioned the Aquatic eDNAtlas project and website.

The Rocky Mountain Research Station maintains the website that includes a national grid of potential eDNA sampling sites, available for download, which allows users to view field sampling points that are systematically spaced at ~1-km intervals along river and stream networks across much of the U.S. Each site is assigned a unique identification code in the eDNAtlas database to ensure that it can be tracked and matched to geospatial habitat descriptors and species sampling results. Knowledge of aquatic species occurrence assists in prioritizing stream segments for restoration, removal of nonnative species, and other district and forest-level management decisions.:



Using eDNA sampling to inform fish eradication efforts

Scientists with RMRS's National Genomics Center for Fish and Wildlife Conservation have developed best practices for application of environmental DNA (eDNA) to fish eradication efforts. Kellie Carim, aquatic research biologist and tribal project Ccoordinator, has been working on brook trout eradication projects using a targeted eDNA approach in Montana with Montana Fish, Wildlife, and Parks, and in eastern Washington in collaboration with the Kalispell Tribe and Washington Department of Fish and Wildlife. Brook trout were introduced to the western U.S. in the mid-1800s and cause negative impacts to native species like cutthroat and bull trout. By using eDNA for eradication projects, managers are now more confidently able to determine when an eradication project has been 100 percent successful. While the most effective way to remove invasive trout is to perform a chemical removal, it is expensive, requires a large crew and large volume of chemicals, and can cause impacts to other organisms, such as invertebrates in the stream. Tools like eDNA can efficiently remove any guesswork about where the target species is and therefore help managers more efficiently mark the area that needs treatment at the beginning of the project, which will reduce the overall treatment area and project costs. These methods have been widely shared with land managers including through Science You Can Use and a webinar.

The FIRE-BIRD tool for understanding suitable woodpecker habitat

RMRS scientists have developed the FIRE-BIRD tool, an ArcGIS toolboxto map habitat suitability for disturbance-associated woodpeckers of conservation concern to help inform locations for management activities in predominantly burned forests of the Inland Northwest and Northern Sierras. The suite of species currently included (black-backed [*Picoides arcticus*], white-headed [*Dryobates albolvartus*], Lewis's [*Melanerpes lewis*], and hairy [*D. villosus*] woodpeckers) makes the GIS tool best suited for

postfire management and restoration treatments in dry mixed-conifer forests. Because each woodpecker species requires different habitat characteristics for population persistence in a post-wildfire landscape, these habitat characteristics should be considered when managers are developing salvage logging and restoration projects. Increases in size and severity of wildfire and insect outbreaks are expected to continue with climate change, providing more opportunities for post-disturbance salvage logging and forest restoration activities. We developed FIRE-BIRD, a GIS tool to help managers make the best decisions for maintaining habitat of key wildlife species, while still allowing economic benefits to local communities. This tool was shared widely with land managers through Science You Can Use and a land manager-focused webinar this year.

Understanding fire, climate change and management impacts on spotted owls

Scientists at the Rocky Mountain Research Station are helping managers better understand how climate change, wildfire, and forest management interact to drive forest changes and what these changes mean for the ecology and conservation of the Mexican spotted owl. In the Southwest, scientists and managers are working together to find ways to reduce the risk of future megafires while also maintaining critical nesting habitat. Wildfires in the western United States are expected to increase both in size and severity in coming decades and these trends are likely to accelerate large-scale habitat loss and fragmentation for the spotted owl in the Pacific Northwest, California, and the Southwest. All three subspecies that occupy these regions have declined over the last century, and the Mexican and northern subspecies are listed as threatened under the Endangered Species Act in the United States. Our recent findings include: (1) Within the range of the Mexican spotted owl, a 13-fold increase in area burned is expected by the 2080s;

(2) High-severity fire can decrease habitat suitability considerably for nesting Mexican spotted owls; (3) Areas with suitable nesting habitat may be more prone to high-severity fire; and (4) Some types of fire can result in improved habitat for prey and food resources for the Mexican spotted owl, but that improvement may not compensate for the loss and degradation of nesting habitat. We are currently completing a *Science You Can Use Bulletin* and have a land manager-focused webinar planned to broadly distribute findings to land managers.

Evaluating Myrtle rust pathogen genetic diversity and invasive threats

The myrtle rust pathogen poses an invasive threat to tropical and subtropical global regions. RMRS scientists, along with university, land management, and science partners worldwide are using genetic analyses to determine which trees and geographic regions are most at risk. These findings are being shared globally to curb disease expansion. Currently, an invasive myrtle rust disease pathogen (*Austropuccinia psidii*) is spreading around the globe, which threatens native and planted trees and shrubs in the *Myrtaceae* family, such as eucalypt, guava, rose-apple, and ‘ōhi’a. Though the disease is expanding its geographic range and poses potential threats to forest ecosystems world-wide, we are only beginning to understand the genetic structure of pathogen populations, possible pathways of spread, and potential sources of introductions.

Genetic analyses were conducted on myrtle rust pathogens from eastern Asia, Australia, the Pacific Islands, Florida, United States of America, the Caribbean, Central America, and Sound America. At least three pathogen biotypes (closely genetically related) were found to occur including a pandemic

biotype. The pandemic biotype is present in the USA (as well as Costa Rica, Mexico, Jamaica, and Australia) and is capable of infecting multiple host species. Bioclimatic modeling is being used to predict suitable climate space (potential distribution) of three pathogen biotypes to predict geographic areas where each myrtle rust pathogen biotype poses an invasive threat.

The invasive myrtle rust disease pathogen threatens native and planted trees and shrubs in the *Myrtaceae* family.

Science-based decision trees for forest managers using mastication

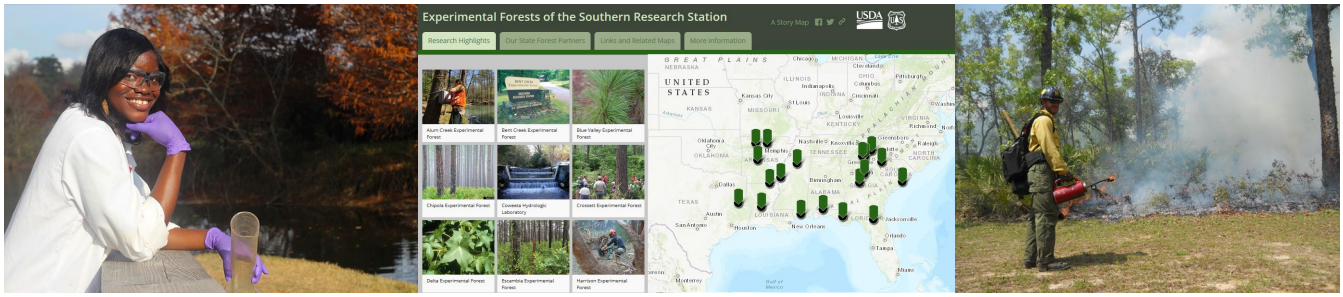
Mastication is an important tool for reducing fire risk in some situations. Mastication works by reducing forest vegetation into small chunks by grinding, shredding, or chopping material with specialized equipment. RMRS scientists have synthesized the potential benefits of mastication as a forest management tool and presented these findings in the form of a set of decision trees. These decision trees are designed to guide land managers in choosing the right treatment option for a site and management objective(s). We published a general technical report entitled To Masticate or Not: Useful Tips for Treating Forest, Woodland and Shrubland vVgetation detailing the most upto-date information on

mastication. A Science You Can Use Bulletin was created for and distributed to land managers as an easy-to-use companion to the report. Important factors include the type of equipment used, operator experience, and site factors like slope, soils, and presence of nonnative species. Additionally, mastication can increase the abundance of fine fuels and, if ignited, these fuels can smolder for long periods; therefore, mastication may not always be an appropriate forest treatment.

Understanding patterns of ponderosa pine regeneration following large, high-severity wildfires

A group of RMRS scientists, along with collaborators at Northern Arizona and Colorado State University, are investigating factors that influence regeneration of ponderosa pine following large, high-severity wildfires. Many recent wildfires in ponderosa pine forests have burned with high-severity across large, contiguous areas. These high-severity patches stand in stark contrast to the low- and moderate-severity patches that dominated fires in ponderosa pine forests historically, leaving managers uncertain about ponderosa pine's ability to regenerate successfully within them. Elevation, aspect, climate, and the presence/amount of other regenerating vegetation are thought to influence whether ponderosa pine regeneration is successful, due to their influence on the growing environment. Our research is helping managers better anticipate recovery within high-severity patches and, in turn, better determine whether and where post-fire management activities would be needed to maintain ponderosa pine forests in the future. Our results provide insight into how the size, shape, and distribution of high-severity patches may influence recovery patterns for burned ponderosa pine forests. Ponderosa pine forests may recover in portions of high-severity patches that are close to surviving trees, particularly if topo-climatic gradients are also favorable. Farther from surviving trees, recovery may be more apt to be

to a ponderosa pine woodland, grassland, shrubland, or forest dominated by sprouting species. Where the return of a ponderosa pine forest is desired but not anticipated to occur, planting may be a viable management strategy. Planting with some level of fine-scale spatial aggregation would best mimic the spatial patterns we observed occurring naturally. A *Science You Can Use* bulletin is currently being developed to share these findings broadly with land managers along with a planned webinar.



Southern Research Station

The Southern Research Station (SRS) includes research work units across 13 southern states and employs around 300 people, including close to 100 research scientists. SRS research advances many areas of forestry science: the use of prescribed fire; hardwood and softwood silviculture, harvesting, and utilization; protection of drinking water supplies and water quality; sustainable management of wildlife habitat; and the control of insects, diseases, and invasive plants. SRS partners with the Southern Region of the National Forest System to conduct research on a network of 19 experimental forests.

Throughout FY20, SRS focused on research and technology that would foster productive, sustainable use of public and private lands. SRS shared these innovations with partners and stakeholders, including:

- 442 scientific publications
- 101 tours to educational and professional organizations
- 116 presentations to lay organizations

- 351 presentations to research and professional organizations
- 70 articles in the SRS online science magazine, CompassLive
- 200+ posts to more than 5,900 followers on Twitter
- 50+ posts to more than 12,000 followers on Facebook

Some highlights of these outreach, science communication, science delivery, and technology transfer efforts are listed below.

Science in Practice webinars provide applied take-aways for managers

A new series of thirty-minute webinars highlight recent research and focus on practical management implications for colleagues from the Forest Service Southern Region, Southern Group of State Foresters, and the Southern Research Station. The "Science in Practice" webinar series is a new communication tool intended to connect scientists, managers, field technicians, and practitioners. Particularly during COVID-19, where travel and in-person meetings are not possible, brief webinars have been a successful tool for sharing research updates. The series began in July 2020 and is averaging 65 attendees per session, with recent sessions attracting more than 100 attendees. Topics have ranged from bat habitat, to invasive species,

oak and chestnut regeneration, and remote sensing products. The online webinars are free and available for anyone to attend. Find recordings and key messages from past webinars and upcoming webinars here: https://www.srs.fs.usda.gov/webinars/science-in-practice/.

A new tool for fighting laurel wilt disease

A fungus called *Acaromyces ingoldii* produces potent compounds that inhibit the laurel wilt pathogen, *Raffaela lauricola*, as a team of SRS scientists and partners discovered. Currently, there are limited options available for managing laurel wilt disease and they are generally ineffective for long-term management. This research could lead to new options for managing the spread of laurel wilt disease across the southeast.

In the southeastern U.S., the geographic distribution of laurel wilt disease on redbay, sassafras, and swampbay has expanded rapidly in recent years, with significant ecological impacts on forest ecosystems, and some economic impact on avocado production as well.

Ongoing efforts to address this threat to the southern forests includes exploring potential control measures to reduce the spread of the disease. Routine assessments of fungi associated with bark beetles from loblolly pine led to isolation of an unknown fungus that appeared to have broad-spectrum antifungal activities. The fungus was identified as

Acaromyces ingoldii, and further investigations showed that the secondary metabolites produced by the fungus significantly inhibited the growth of the laurel wilt pathogen *R. lauricola*. Findings from the study represent a very encouraging preliminary effort in identifying natural compounds with fungicidal/fungistatic activities against *R. lauricola* that could be useful in an integrated management approach against the spread of laurel wilt disease. For more information: https://www.srs.fs.usda.gov/pubs/59072.

Bursts of longleaf pine seed production described with a new index

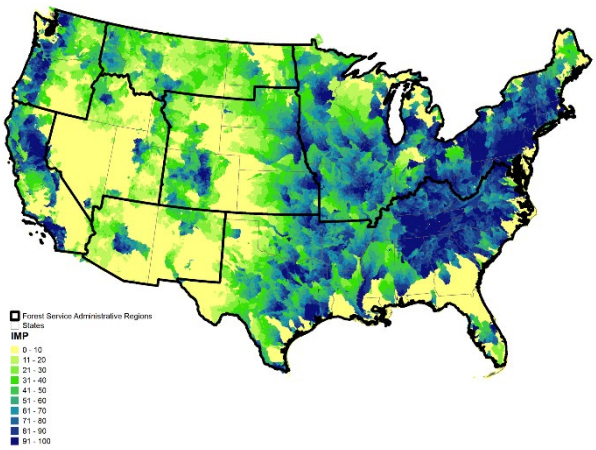
Longleaf pine cone production varies from year to year. Understanding the causes and patterns of this variability will aid in restoration of longleaf pine ecosystems. A burstiness index was developed to help explain some of the ups and downs of cone production.

Both longleaf pine and Chinese Torreya produce abundant seed in some years, but not in other years. A good seed production year, or burst, is frequently followed by a longer period of poor seed production. A burstiness index was developed to identify the thresholds and time intervals that indicate seed production bursts. Results indicated that the average time between bursts was longer for episodes of higher seed production for both tree species. Therefore, complex seed production systems may be governed by generic principles that are common to a number of species. Understanding burstiness in tree seed production may provide new knowledge about tree growth dynamics and reproductive behavior.

Foresters can estimate when the next episode of high seed production is likely to occur and identify sites with short lulls between periods of high seed production. For more information: https://www.srs.fs.usda.gov/pubs/59712.

Forests to faucets: Visualizing forests' role in supplying drinking water across the U.S.

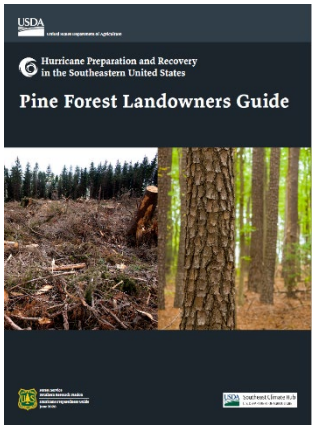
Forests provide numerous ecosystem services that support the U.S. economy and public wellbeing. In particular, forests provide more clean and stable water than any other land use. To better understand this ecosystem service, SRS scientists and partners in State and Private Forestry and the National Forest System have updated the Forests to Faucets mapping and analysis tool, Forests to Faucets Version 2(F2F2). The study integrated online maps, watershed models, historic and future projections of climate and land use change, and surface drinking water withdrawal data.



The result is a user-friendly tool that lets forest managers identify important watersheds for drinking water supply based on the population served, forest cover, riparian condition, and hydrology. The tool can also assess threats to water supply under current and future climate and land uses conditions, offering information for protecting or restoring forests that are important for drinking water. The F2F2 maps can be incorporated into broad-scale planning, such as State Forest Action Plans, and can help identify vulnerable watersheds for further local analysis. In

addition, information generated from F2F2 can be used in other decision support tools to provide spatial information about surface drinking water management. Ultimately, sound management of forests for clean drinking water supply benefits the American public as a whole. For more information: https://usfs.maps.arcgis.com/apps/MapSeries/index.html?appid=e84fc83c8be542079d3c1d489d45be21.

Hurricane preparedness and recovery guides for southeastern forests, farms, and ranch producers



Each year, hurricanes cause billions of dollars in agricultural and forestry losses, and these losses grow as climate change continues to contribute to more severe hurricane seasons. Producers—farmers, ranchers, and foresters—need to minimize their losses and reduce their post-hurricane recovery time to remain profitable. Existing information on hurricane preparedness and recovery has tended to be scattered and inconsistent. The USDA Southeast Climate Hub worked with university Extension, USDA Forest Service, and Farm Service Agency subject matter experts to develop a centralized resource and make current knowledge and best practices more accessible. The result is a series of 23 guides, focused on the most economically important commodities for all coastal states in the southeastern U.S. The guides include management practices and are designed to reduce economic loss and decrease the time to full recovery.

Each guide begins with steps to build operational resilience to hurricane impacts. This is followed by short-and long-term preparation guidance to help prepare for personal, worker, and operational safety

before a hurricane strikes. Finally, each guide provides post-hurricane recovery steps to maximize safety and speed up recovery. As climate change creates more frequent and severe hurricanes, the importance of resources such as these guides will only grow. For more information: https://www.climatehubs.usda.gov/hubs/southeast/topic/hurricane-preparation-and-recovery-southeast-us.

Plant community inventory of the South Fourche Botanical Area in Arkansas ends with a twist

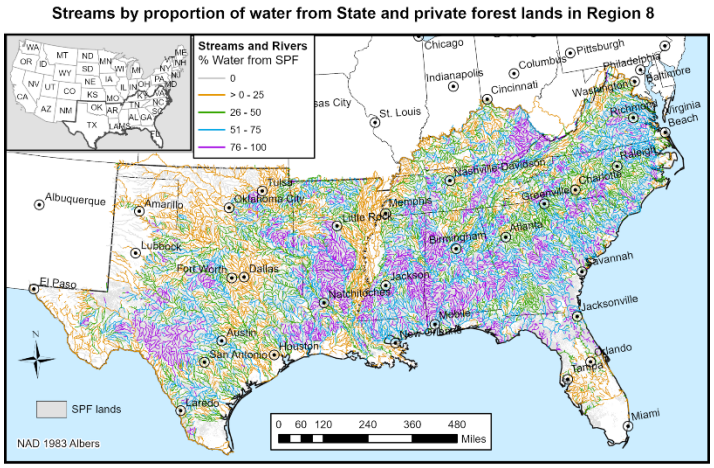
The Ouachita Mountains in Arkansas are home to a number of endemic plant species, many of which are found only in glades, barrens, open woodlands, and river scour-prairies.

The South Fourche Botanical Area was designated by the Ouachita National Forest in 2005 because of its unique plant communities, including a hanging oxbow, a salt lick, several groundwater seepage areas, as well as some high-quality glades, woodlands, and river scour-prairies.

In 2016, Forest Service researchers began a full inventory of the plant diversity of the area. Botanists from the state of Arkansas and The Nature Conservancy joined the effort. Researchers identified eight community types and tallied nearly 700 plant species, including 13 of conservation concern in Arkansas.

Because of the survey, more than 100 new species have been added for the county where this area is located. The Ouachita twistflower (*Streptanthus squamiformis*), previously thought to be limited to portions of three counties in western Arkansas, was found at the South Fourche Botanical area – a 50 mile range extension for a species whose range was only about 30 miles wide. For more information: https://www.naturalareas.org/2019_conference.php.

Quantifying the role of state and private forest lands in providing surface drinking water supply for the southern U.S.



Forests provide the most stable and highest quality water supplies among all land uses. The southern U.S. is heavily forested and the fastest growing region in the nation. Therefore, it is critical to understand the role of forested lands in providing water across the South. Approximately 55 million people in the South – about half the population –derive some portion of their drinking water from state and private forest (SPF) lands.

This study provides a systematic assessment of the interactions among water, forests, and people. Findings highlight the connections between SPF lands, water supply in the South, and the need for sound forest management to ensure clean and stable water supplies for southern communities now and

in the future. In addition to peer-reviewed publications, the researchers produced a collection of ArcGIS Story Maps with the South Carolina Forestry Commission. The collection includes interactive maps, data tables, and videos for each of the 13 states and across the South.

The goal is to provide resource managers with information needed to show the important role state and private forest lands play in provisioning drinking water for southerners. Because of the innumerable water-related benefits of forest lands, many water supply authorities seek to maintain forest lands in their watersheds. Healthy forested watersheds protect drinking water quality and minimize water treatment costs. For more information: https://www.fs.usda.gov/treesearch/pubs/59637.

Sawfly GenUS: a new tool to identify woodwasps and other sawflies

Woodwasps and sawflies are pests of many species of plants including hardwood and coniferous trees. Typically, native species are in equilibrium with the ecosystem and are of little long-term concern. Exotic species that have been introduced without natural predators can become major pests. The mostly European, woodboring Sirex woodwasp (*Sirex noctilio*) was accidentally introduced to plantations of Monterey pine in New Zealand over 100 years ago and has now become the most significant pest of pines in the Southern Hemisphere including Australia, South Africa, and South America. Some plantations in Australia experienced 80 percent loss due to this species.

The Sirex woodwasp was recently discovered near New York, and it is expected to threaten pines in the southeastern U.S. in the future. There are also exotic and native needle- or leaf-feeding sawfly species (*Diprion*, *Neodiprion*, *Pristiphora*) on larch, spruce, and pines and slug-like *Caliroa* species on oaks that can cause severe damage in outbreak years.

Many of these pest species are difficult to identify except by experts, because they superficially resemble benign species. There are about 30 species that resemble *Sirex noctilio* in the Western Hemisphere. Researchers developed an easy to use, online, heavily illustrated tool that enables non-experts like foresters, land managers, and extension agents to identify native and exotic sawflies and woodwasps and determine if they are a threat that requires management. The best way to protect federal, state, and private forests from insect pests is to prevent exotic species from becoming established. This can only be accomplished with tools like Sawfly GenUS to identify native and exotic species. The sawfly tool can be found at: https://idtools.org/id/sawfly.

Scientists embrace shared stewardship to deliver silviculture research

SRS scientists developed, hosted, and participated in a four-day online short course held July 21-24, 2020. The course provided training on the principles and practices of silviculture and closely related disciplines for managing upland hardwood-dominated forests in the eastern U.S.

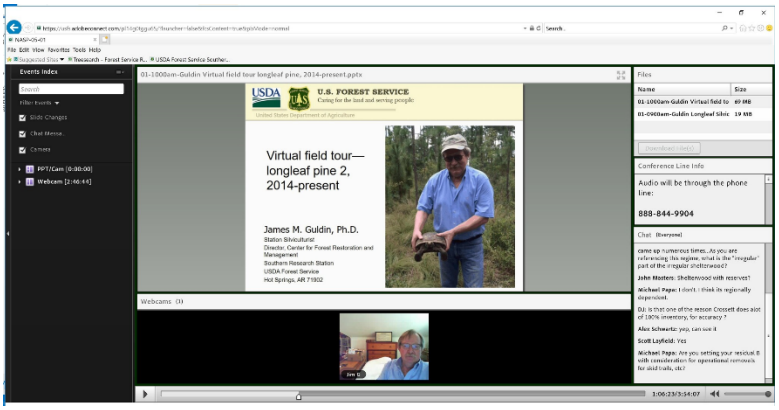
The course was attended by more than 100 managers from state forestry agencies in Alabama, Georgia, Kansas, Kentucky, North Carolina, South Carolina, Ohio, Tennessee, and Virginia; other federal agencies, including the Department of Defense; and consulting foresters. The course was originally scheduled to be in-person, but the organizers shifted to a virtual format in an effort to disseminate information while keeping participants and speakers safe during the COVID-19 pandemic.

Experts from multiple USDA Forest Service deputy areas, including the Southern Research Station, Northern Research Station, and Forest Health Protection, presented science-based information on a variety of topics. Other presenters were from the University of Tennessee and University of Kentucky.

Presenters discussed regeneration methods and outcomes; forest health; ecological effects of fire in upland hardwood systems; fire effects on timber quality; American chestnut restoration; reviews and drivers of timber production and markets; silviculture effects on wildlife and habitat; and management of oak woodlands, mixed pine-hardwood stands, and degraded hardwood stands.

The course provided land managers with tools and information needed to prepare and implement technically sound silvicultural prescriptions designed to meet multiple objectives. The course was recorded and will continue to provide information to land managers seeking the best available science for actively managing upland hardwood systems. The course is available on the Upland Hardwood Ecology and Management website: https://www.srs.fs.usda.gov/uplandhardwood/courses-and-webinars/virtual-workshop/.

The Southern Pine Module goes virtual



Every two years, SRS scientists are invited by experts in the Southern Region of the USDA Forest Service to host the Southern Pine Module, a ten-day, field-based workshop that highlights the ecology and management of loblolly, shortleaf, slash, and longleaf pines on public lands across the South.

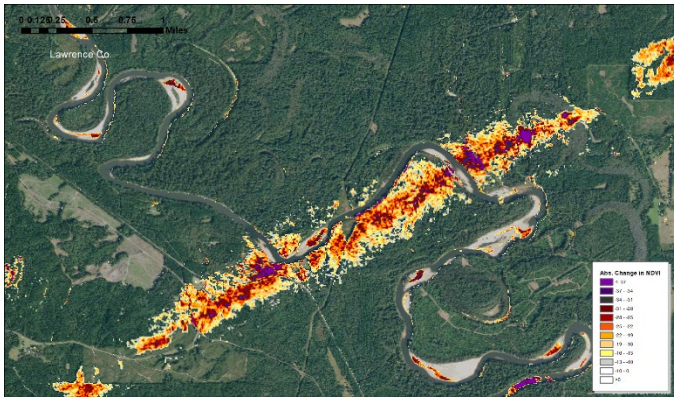
The goal of the module is to provide the advanced education and training that agency foresters need to obtain the silvicultural certification required to conduct active management on federal lands. Due to safety protocols and travel restrictions during the COVID-19 pandemic, coordinators converted the module into a virtual online event, featuring four hours of presentations and daily discussions across the ten-day session.

Topics ranged from advances in active forest management strategies and tactics, to markets and economics, and management of genetic resources used in planted stands. Experts also discussed invasive and destructive plants and insects such as Chinese tallow tree and the southern pine beetle.

Although participants missed being in the field, organizers created photo-based virtual field tours in forests where southern pines are managed. One tour stop dated back to the early 20th century using photos and citations from the "Life History of Shortleaf Pine," a 1915 USDA Bulletin by W.R. Mattoon. His descriptions of shortleaf pine a century ago can help guide current efforts to restore that iconic species across the landscape to which it is adapted.

The virtual sessions were recorded, so land managers across the Southern Region can use the recorded sessions in their own training and continuing education activities. The presentations and recordings are available: http://fsweb.srs.fs.fed.us/nasp-module/. For more information: https://www.srs.fs.usda.gov/compass/2020/08/25/the-southern-pine-module-goes-virtual/.

Monitoring forest health during a pandemic: satellite-based remote sensing fills a crucial gap



Assessing damage from natural disturbances is an ongoing need for state and federal forest managers. Before the 2020 growing season began in the South, tornadoes struck from Texas to North Carolina. Two sequential frosts set back the growing season across Tennessee, Kentucky, and Virginia. As the summer went on, vast sections of Michigan and New York were defoliated by the nonnative gypsy moth, then hurricanes inundated low lying areas of the South.

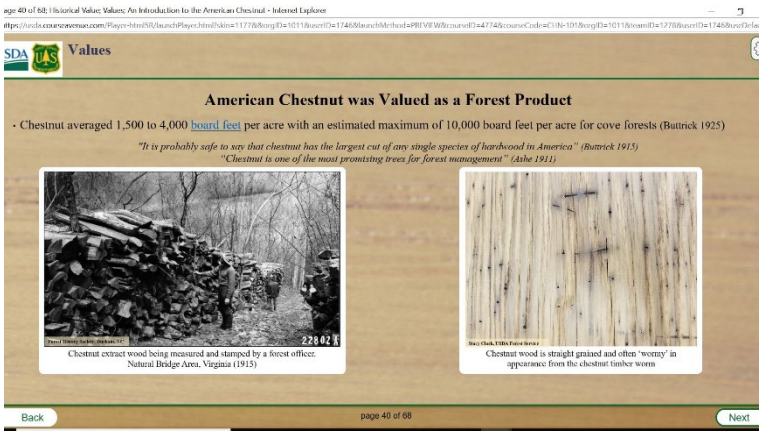
For decades, the USDA Forest Service and state agencies have tracked disturbances such as these in partnership, primarily through aircraft and ground observations. Those capabilities were curtailed in 2020 by coronavirus restrictions. The forest monitoring mission would need to rely on existing and new remote sensing technologies during the pandemic.

Southern Research Station researchers stepped up to this challenge by working closely with state and federal partners to ensure maximum use of existing *ForWarn* products and the new *HiForm* workflow that makes use of high-resolution satellite imagery. Researchers worked closely with partners to map damage and build capacity through free sharing of analysis tools and one-on-one exchange. This communication helped managers track disturbances and provided additional insights for the researchers. Given the long-term cost savings and safety benefits of rapidly evolving remote sensing technologies, this intense 2020 team effort should continue to reap rewards for years to come. Explore the tools at https://forwarn.forestthreats.org/ and https://hiform.org/.

Improving technology transfer for land managers: a new approach focused on the American chestnut

Forest management requires the best available scientific information, but obtaining this information can be challenging, especially as budgets shrink. In order to meet these information needs without cost to land managers, an SRS research forester is developing an online educational course – as well as processes that others can readily apply to share relevant research results.

One interactive educational course is complete and provides information on the ecology, silvics, and the demise of the American chestnut (*Castanea dentata*), a tree that once dominated 200 million acres of the eastern U.S.



The course includes glossaries, downloadable documents, a bibliography, audio accompaniment, and videos. The course will be peer-reviewed and published online through AgLearn for USDA users and on a separate website for state foresters, private landowners, and other users outside the agency. Course surveys and assessments will be used to track user groups, refine and improve the course, and develop future courses.

Technology transfer products, such as this online educational course, allow the Forest Service to excel as a high-performance agency by providing easily accessible and engaging training to National Forest System managers. Additionally, the knowledge shared through the course can benefit the public. For more information: https://srs.fs.usda.gov/products/courses/#chestnut.

An integrated management strategy for hemlock woolly adelgid is now available

A nonnative invasive insect, the hemlock woolly adelgid (HWA), threatens the ability of natural resource managers to maintain eastern and Carolina hemlocks as critical components of unique forest ecosystems in eastern North America. Although substantial progress has been made in both chemical and biological control of HWA, neither of these tactics applied alone is expected to provide adequate control of HWA throughout its introduced range.

A new USDA Forest Service resource manager's guide titled *Integrating Chemical and Biological Control of the Hemlock Woolly Adelgid* presents a strategy for using biological and chemical control together in the same forest stands. The goal of the strategy is to prolong hemlock health on certain hemlock trees through temporary insecticide protection, while simultaneously establishing predators on nearby untreated trees. Temporarily-protected hemlocks are expected to eventually support predators after their chemical treatment wears off. Guidelines for site selection, treatment timing, spatial considerations, monitoring, and assessment are included. The guide is intended as a starting point for a more sustainable approach to HWA management that reduces the amount of insecticide applied and that can be integrated with additional management tools as they are developed. For more information: https://www.fs.usda.gov/treesearch/pubs/59529.

Technology and Development Centers (Missoula and San Dimas)

History

Originally tasked with repurposing surplus military equipment to aid in fighting wildfires, the National Technology and Development Program (NTDP) started life as equipment development centers located in Missoula, MT and San Dimas, CA. These equipment development centers were responsible for many of the life- and cost-saving advances common to today's firefighters: standardized hoses, pumps, couplings, rappelling and parachuting equipment, and the essential fire shelter, credited with saving more than 300 lives on the fire line.

The center's scope eventually expanded beyond wildfire, and the centers were combined into one organization: the National Technology and Development Program. Today, the program works on

projects touching on forest management, recreation, engineering, occupational safety and health and more.

The National Technology and Development Program now categorizes its work within three areas: application of innovative science and technology, knowledge synthesis, and specifications and standards.

The Mission of the National Technology and Development Program is to provide Forest Service employees and partners with practical, science-based solutions to resource management challenges by developing and managing specifications and standards, synthesizing and sharing knowledge, and applying innovative science and technology.

To support the Technology and Development Program's mission, the Program has a cadre of personnel with far-reaching skills. Engineers, technicians, foresters, biologists, draftsmen, writers, and publishers all work as project team members to support the problem-solving goals of the program.

The Program serves as a resource to three of the four deputy chief areas in the Forest Service: National Forest System, Business Operations, and State and Private Forestry.

The program partners with the fourth deputy chief area, Research and Development, as well as academia, private industry, and other governmental agencies to achieve its mission. The Program's team approach to creative problem solving has resulted in some unique and innovative solutions. Some of those solutions include:

- The Sweet Smelling Toilet
- Redesigned Fire Shelter
- Water-Based Tree Marking Paint
- Improved Helicopter Rappel Rope and Descender
- Electronic Forms for National Visitor Use Monitoring
- Machine Vision System for Forest Management (Patent & CRADA)
- Augmented and Virtual Reality Based Training
- Fueling Systems for Small Engines (CRADA)

International Institute of Tropical Forestry

The International Institute of Tropical Forestry (Institute) is housed in San Juan, Puerto Rico where it serves people from Puerto Rico, the U.S. Virgin Islands, the Caribbean, and central and south America. The Institute has an international mission as well as Research & Development and State and Private Forestry missions. It has been a unit of the Forest Service since 1939 and it specializes in tropical forestry, a specialty for which it is globally known given the level of excellence and continuity of its programs. As an example, the Institute pioneered tropical forestry in this hemisphere and developed the

field at a time when there was no professional tropical forestry being practices in the region. Today, the programs of the Institute support the Forest Service mission in the only tropical forest in the National Forest System, the El Yunque National Forest. This forest is also an experimental forest in its entirety (unique in the agency) and is the most-studied tropical forest in the hemisphere. The results of the research program of the Institute are broadly transferred to a diverse network of collaborators including non-governmental organization, municipal and state governments, landowners, land management practitioners, international organizations, and other scientists, to name a few. Through electronic media, the Institute now reaches millions of people.

Recent outcomes of Institute programs include:

Comprehensive understanding of the effects of hurricanes on tropical forests, including uncovering invisible effects through microbial action that may prove key to processing enormous quantities of debris produced by hurricanes and other extreme events.

Established the first experiment dealing with the response of tropical forests to increases in air temperature. Experiments on the effects of droughts and fire on tropical forests are also underway and yielding information relevant to forest conservation.

How do cities think? How can cities be made more adaptive and resilient to extreme events? These questions are being addressed through networks of tropical and temperate cities. Research shows that

tropical cities are different from temperate cities in terms of their green infrastructure and social-ecological responses to extreme events.

The Institute transfers the results of its research to collaborating communities and landowners through programs that include tree cities, forest stewardship management plans, urban councils, land acquisition for conservation purposes, and new eco-tourism enterprises; all are programs that provide jobs and economic development to people.

The Institute also has a conservation education program that reaches underrepresented populations from kindergarten to post-doctoral levels.

7.3. Metric Tables.

TABLE 1. Collaborative Relationships for Research and Development.
*ND-no data available.

Forest Service (FS)	FY2016	FY2017	FY2018	FY2019	FY2020
Total number active CRADAs[1]	73	74	22	58	102
Number newly executed CRADAs	33	34	9	36	50
All other Non-CRADA/MTA Agreements	ND	ND	ND	ND	2,872

[1] Starting in FY 2019 the Forest Service will count all agreements under the authority of 15 U.S.C. 3710a as CRADAs

TABLE 2. Invention Disclosure and Patenting
*ND-no data available.

Forest Service (FS)	**FY2016**	**FY2017**	**FY2018**	**FY2019**	**FY2020**
Total number new invention disclosures[1]	24	20	10	9	12
University co-owned	2	7	1	2	5
Total number patent applications filed[2]	12	11	7	7	10
University co-owned	7	6	0	1	5
Total number patents issued	9	5	5	3	4
University co-owned	4	4	4	0	0

1. Inventions arising at the federal lab.

2. Includes U.S. patent applications, foreign patent applications filed on cases for which no U.S. application was filed, divisional applications, continuation-in-part applications, and provisional applications.

TABLE 3. Profile of Active Licenses
*ND-no data available.

Forest Service (FS)	FY2016	FY2017	FY2018	FY2019	FY2020
Total number active licenses	19	19	9	11	13
Executed to small businesses1	2	2	1	0	ND
Executed to startup businesses2	1	1	1	0	ND
Executed to universities	16	16	1	0	ND
Invention licenses3	19	19	9	11	13
Executed to small businesses	2	2	1	0	ND
Executed to startup businesses	1	1	1	0	ND
Executed to universities	16	16	1	0	ND

TABLE 4. Characteristics of Income Bearing Licenses

Forest Service (FS)	FY2016	FY2017	FY2018	FY2019	FY2020
Total number of income bearing licenses	19	19	9	11	13
Exclusive	18	18	9	11	13
Partially exclusive	0	0	0	0	0
Non-exclusive	1	1	0	0	0

1. Invention licenses refer to licenses resulting from a patent.
2. Other IP licenses included biological materials licenses and plant variety protection licenses.

TABLE 5. Income from Licensing

Forest Service (FS)	FY2016	FY2017	FY2018	FY2019	FY2020
Total income all active licenses	$2,878	$2,634	$3,122	$800	ND
Invention licenses	$2,878	$2,634	$0	$800	ND

ND = Funds not received in 2020

FY19 FS Accomplishment Metrics in support of the REE Action Plan

Fiscal Year: 2020		
Products (Software/Web & Multimedia), Peer Reviewed and Non-Peer Reviewed Publications		
Outcomes	***Product Type***	***Total Entries***
Publications	Formally Refereed	1179
Publications	Informally Refereed	591
Publications	Non-Refereed	135
Publications	All types	1905
Publications Articles	In Journals	1152
Publications Articles	Not in Journals	753
Science Delivery	Activities	1194
Science Delivery	Products	239

FSIS communicates safe food handling practices to consumers.

FSIS applies the latest technologies to assure the safety of meat, poultry and egg products.

FSIS activities lead to safer food for consumers.

7.0. Food Safety and Inspection Service (FSIS)

7.1. Mission Statement

The Food Safety and Inspection Service (FSIS) is the public health agency in the U.S. Department of Agriculture (USDA) responsible for protecting the public's health by ensuring the safety of the Nation's commercial supply of meat, poultry, and egg products. FSIS ensures food safety through the authorities of the Federal Meat Inspection Act, the Poultry Products Inspection Act, and the Egg Products Inspection Act, as well as humane animal handling through the Humane Methods of Slaughter Act.

7.2. Nature and Structure of the Program

FSIS laboratories use the latest methods to test for chemical, microbiological and physical hazards in meat, fish of the order Siluriformes, poultry, and egg products. FSIS collects scientific information and data using our laboratories and produces a number of comprehensive reports related to the Agency's sampling programs. These reports allow FSIS to publicly share information about the Agency's' sampling programs, discuss the statistical and policy basis for these programs and future changes to develop new programs and modify existing programs. as well as through partnerships with Federal Agencies, universities, and industry. FSIS generated data can be found on our website: https://www.fsis.usda.gov/wps/portal/fsis/topics/science

FSIS reviews new technologies that companies' employ to ensure that their use is consistent with Agency regulations and will not adversely affect product safety, inspection procedures, or the safety of FSIS inspectors. In addition, the Agency leverages a variety of strategies and technologies to conduct educational outreach to consumers (see section 7.3).

The Agency prioritizes and communicates its research needs to our partners and stakeholders during meetings with Agency leadership and scientists, seminars at universities and scientific conferences, and postings on the FSIS website. The list of current FSIS research priorities includes:

- Develop or improve rapid methods for screening chemical compounds in FSIS regulated products

- Develop or refine technologies to reduce pathogen detection time, including improved sample preparation methods

- Develop or refine technologies for virulence/pathogenicity characterization of pathogens; and

- Identify and/or develop and evaluate the effectiveness of pre- and post-harvest interventions to reduce levels of pathogens in FSIS regulated products.

More information and a complete list of current FSIS Research Priorities is available at: https://www.fsis.usda.gov/wps/portal/fsis/topics/science/food-safety-research-priorities

In FY 2020, FSIS proposed twelve new food safety research studies, associated with existing priorities. These new research studies include improving pesticide screening methods, developing new methods for screening ante-mortem animals for contaminants, improving microbial detection methods, and improving our understanding of antimicrobial resistance in foodborne pathogens. During FY 2020, the FSIS Research Priorities and Food Safety Research Studies pages on the FSIS website were each accessed on more than 6,900 occasions. Approximately 55% of page views were by new visitors, and about 85% of visitors were referred by search engines or partner agency websites.

7.3. Activities in FY 2020

Facilitating the Application of New Food Safety Technologies to Food Production

FSIS reviewed and approved multiple requests to use new food safety technologies during FY 2020. FSIS evaluated new technologies designed to enhance food safety, including new commercial pathogen interventions, process innovations, and the use of new ingredients. FSIS posts brief summaries of the technology on the FSIS New Technology Information Table (https://www.fsis.usda.gov/wps/portal/fsis/topics/regulatory-compliance/new-technologies/new-technology-information-table) to increase public and industry awareness of available new technologies.

In FY 2020, FSIS reviewed 120 new technology submissions. New technology submissions included the use of new or reformulated ingredients, egg products, retained water protocols (RWP), online reprocessing systems (OLR), and offline reprocessing substances (OFLR).

Facilitating the Application of Food Safety Research Findings to Produce Safe Food

The Agency released thirteen guidance documents, including three Hazard Analysis and Critical Control Point (HACCP) models, to assist industry with identifying and applying relevant scientific findings to produce safe meat, poultry, and egg products. Additional information on guidance documents can be found on our website at the link below: **https://www.fsis.usda.gov/wps/portal/fsis/topics/regulatory-compliance/guidelines**

FSIS Uses Science-Based Food Safety Information to Educate Consumers and Other Stakeholders

On September 22, 2020, FSIS hosted "*Salmonella*: State of the Science," a virtual public meeting on long-term strategies to reduce *Salmonella* in FSIS products. FSIS shared the "Roadmap to Reducing *Salmonella*" to further outline the Agency's science-driven approaches to target *Salmonella.* At this meeting, FSIS presented its roadmap which described how the Agency advanced programs and policies that are science-based, data-driven, and promote innovation to reduce *Salmonella* and other pathogens in meat, poultry, and egg products. The roadmap described current FSIS programs and future activities to drive progress toward meeting the Healthy People 2030 public health goals. Topics discussed included:

- *Salmonella* presence in FSIS regulated products
- Modernization of inspection system
- The role of FSIS Laboratories and sampling methods to reduce *Salmonella* in FSIS regulated products
- *Salmonella* performance standards
- Consumer research and education; and
- Future scientific strategies for controlling *Salmonella*.

FSIS gave multiple presentations at the meeting, as listed below:

Title	FSIS Speakers
Salmonella - State of the Science	Mindy Brashears
Salmonella Trends – What the Science Tells Us	Kis Robertson Hale
Scientific Basis for Performance Standards	Denise Eblen
How FSIS Laboratories Support Efforts to Reduce *Salmonella*	William Shaw
Role of Science in Modernizing Inspection Systems	Philip Bronstein
Role of Science in Consumer Research and Education	Carol Blake
Role of Research at FSIS	Isabel Walls
Future Challenges and Opportunities	Mindy Brashears

In 2020, FSIS and the U.S. Food and Drug Administration (FDA) hosted a joint webinar and launched webpages to provide information on the respective statutory authorities, roles and responsibilities for cultured animal cell food products, and regulatory points of contact for new food production technology.

FSIS gave multiple presentations at the 2020 International Association for Food Protection Annual Meeting, as listed below:

Category	Title	FSIS Speakers
General Session	US Regulatory Update on Food Safety	Mindy Brashears
Symposium presentation	Regulatory Perspective for Water Reuse in Animal Processing Facilities	Melanie Abley
Symposium presentation	Regulatory Approach to Reduce the Risk of Pathogens Associated with Garde Manger and Specialty Meat Products	William Shaw
Symposium presentation	Regulatory Updates on the Proposed Appendix B (2017)	Scott Updike
Symposium presentation	FSIS Investigation of an Outbreak of Salmonella Infantis in Poultry	Gamola Fortenberry
Symposium presentation	Salmonella Reading Outbreak: the FSIS Perspective	Doug Noveroske

Symposium presentation	U.S. National Residue Program	John Johnston
Symposium presentation	Changing the Face of Federal Outbreak Communications through Consumer Research	Aaron Lavallee
Roundtable presentation	What Don't We Know? Cultured Meat vs. Traditional Meat and Fish Food Safety Concerns	Mathew Michael
Technical session	Consumer Preparation and Thermometer Use for Cooking Not-Ready-to-Eat Frozen, Breaded Poultry Products and Vegetables: Findings from an Observational Study	Chris Bernstein
Technical Session	Inferred Salmonella enterica Serotype from Whole T8-03 Genome Sequencing Data Using SeqSero2	Mustafa Simmons, Jamie Wasilenko, Marie Maier, Aphrodite Douris, Jessica Battles, Joseph Minicozzi, Cesar Morales, Michael Myers, Labeed Ben-Ghaly, Glenn Tillman
Technical Session	Strategic Allocation of Sampling Resources at the United States Department of Agriculture's Food Safety and Inspection Service	Joanna Zablotsky Kufel, Rebecca Fields, Jackson Crockett, Matthew Gonzales, Michelle Catlin, Justin Ronca, ,
Poster	Monitoring and Evaluation of 18 Different Metals in U.S. Meat and Poultry	Alexander Domesle, Oliver Ou, John Johnston, Eric Flynn, Patrick Sisco, Randolph Duverna,
Poster	Detection and Monitoring of 16 PFAS in Beef	Alexander Domesle, J. Emilio Esteban, Ivan Lenov,
Poster	Salmonella and Campylobacter in Chicken Necks, Hearts, Gizzards, and Livers	Erika Stapp-Kamotani, Neal Golden, J. Mark Carter, William Lanier, Nelson Clinch, Yoel Izsak
Poster	Comparison in the Recovery of Campylobacter from Poultry Establishments Using Direct Plating Versus Enrichment Methodologies: Amplified Population or Expanded Population?	Stevie Hretz and Mustafa Simmons
Poster	Research Priorities Identified by the United States Department of Agriculture Food Safety and Inspection Service	Isabel Walls, John Johnston

The first nationally representative web survey about consumer awareness and understanding of recalls and outbreaks was analyzed, and publicized. Key insights include:

- Fifty-three percent of survey respondents reported having at least one person in their household at high risk of foodborne illness (i.e., an older adult, younger child, pregnant woman or individual with a weakened immune system);

- Seventy-two percent of respondents trusted information about food recalls from government sources and local television news, but most respondents preferred to receive this information through local sources (i.e., television news and grocery stores); and

- "Recall fatigue" (the idea that there are too many recalls and consumer shut down or stop paying close attention because they hear too many of them) among consumers does not exist. Seventy-eight percent of respondents recalled hearing 10 or fewer recalls in the past 6 months, which is much lower than the actual number of recalls from FSIS and FDA (around 200), suggesting that respondents do not have recall fatigue.

FSIS and our public health partners at the Centers for Disease Control and Prevention (CDC) and FDA use Whole Genome Sequencing (WGS) to detect and investigate foodborne disease outbreaks. This starts with identifying cases of human illnesses where bacteria from human clinical samples and food samples are closely related genetically. Next, investigators collect epidemiologic information to

generate a hypothesis and to explore the possible link between the food isolate and human illness. An example of the use of WGS to investigate an outbreak is below:

- FSIS investigated a *Salmonella* Dublin outbreak in FY 2020. The FSIS Eastern Laboratory, Microbiology Characterization Branch noted that there were genetic similarities between temporal human *Salmonella* Dublin isolates and FSIS *Salmonella* Dublin isolates recovered from ground beef samples. The alert trigged a national foodborne outbreak investigation led by FSIS and CDC that resulted in a recall to remove affected product from commerce, which prevented additional illnesses. WGS played a critical role in the timely detection of the outbreak, providing important evidence to guide investigators, and establishing a link between human illnesses and FSIS-regulated products.

Transferring Analytical Methods Development Research and New Technologies to FSIS Laboratories for Monitoring Hazards and Regulatory Compliance

FSIS Transitioned to Using Whole Genome Sequencing (WGS) Data from Salmonella Isolates to Determine Serotype

FSIS modernized laboratory methods to determine serotype of Salmonella isolates. For all *Salmonella* positive samples collected after January 1, 2020, WGS data is being used to determine *Salmonella* serotype. FSIS last modernized the *Salmonella* serotype methodology in 2012 when FSIS introduced molecular serotyping to replace traditional slide agglutination technologies for routine analyses. Any

isolates that needed further classification were sent to USDA National Veterinary Services Laboratory (NVSL) for traditional (slide agglutination) serotyping. Using bioinformatics tools that have developed over the last several years, WGS data can be analyzed to determine *Salmonella* serotype. Since 2016, FSIS has performed molecular serotyping in parallel with WGS serotype analysis. FSIS recently performed a comparison of *Salmonella* serotype determination using molecular serotyping and using improved bioinformatics tools to analyze WGS data. Of the 9,842 *Salmonella* isolates sequenced by FSIS since 2016, 98.21% of the serotypes determined by WGS data matched the serotype determined by molecular serotyping and/or USDA NVSL traditional serotyping. This high level of agreement supported the transition to routinely using WGS to determine *Salmonella* serotype and discontinuing the parallel analyses. Using FSIS' current process for performing WGS, serotype information will typically be available 7 days after an isolate is confirmed. FSIS plans to maintain molecular serotyping capabilities and will continue sending isolates to NVSL for further classification in the rare cases where *Salmonella* serotype cannot be determined using WGS. FSIS presented these findings at the virtual 2020 IAFP Meeting.

Laboratory Method Updates

The laboratory system completed three comprehensive method updates. To support the National Residue Program (NRP) and targeted testing efforts, the per- and polyfluoroalkyl method was expanded to include pork, poultry, and Siluriformes fish, as well as cattle plasma. As required by the Farm Bill, the laboratory system expanded species testing capabilities to add the ability to test for cat and dog tissue. In support of the expansion of sampling under the National Antimicrobial Resistance Monitoring

System (NARMS), the laboratory system verified and implemented protocols to test Siluriformes fish and certain cattle lymph nodes for NARMS microbial targets and to screen for carbapenem-resistant bacteria. Additionally, the FSIS laboratories now screen cecal samples from veal, goat, lamb, and sheep as part of the NARMS sampling expansion to new commodities.

In addition, FSIS collaborated with FDA, the Environmental Protection Agency (EPA), and USDA's Animal and Plant Health Inspection Service (APHIS) on issues related to chemicals, residues, and pesticides. Approximately 166,000 samples of FSIS-regulated products were screened in FY 2020 under the National Residue Program, with a violation rate of less than 0.3%.

Cooperative Research and Development Agreements

Material Transfer Agreements

FSIS receives requests from government agencies, academia and private entities for bacterial isolates recovered from meat, poultry, and egg products and the environment in which these products were produced. Isolates requested are typically used for research and/or method development purposes. FSIS shares isolates under material transfer agreements (MTA). In 2020, FSIS completed 10 MTA, as shown below:

Material Transfer Agreements complete in 2020

Bacterial isolate	**Industry, Academia or Federal Partner**
Isolates from Pork Enrichment Broths	Government Partner
Salmonella	Industry
Salmonella Reading	Academia
Salmonella	Government Partner
Salmonella strains	Industry
DNA transfer for SeroSeq	Government Partner
Salmonella	Academia
Campylobacter	Academia
Salmonella Schwarzengrund	Industry
Salmonella serovars	Government Partner

8.0. National Agricultural Statistics Service (NASS)

8.1. Mission Statement

"The National Agricultural Statistics Service provides timely, accurate, and useful statistics in service to U.S. agriculture." The statistics NASS compiles are used by agricultural producers and businesses to ensure an orderly flow of goods and services among agriculture's production, processing, and marketing sectors. Reliable, timely, and detailed crop and livestock statistics help to maintain a stable economic climate and minimize the uncertainties and risks associated with the production, marketing, and distribution of commodities.

NASS data are also vital to policymakers, researchers, and scientists in the agriculture community who depend on reliable and unbiased facts. The Census of Agriculture, conducted every 5 years, provides comprehensive, county-level data about agricultural communities across the United States. NASS statistical data are essential to both the public and the private sector for making effective policy and for production and marketing decisions.

8.2. Nature and Structure of Research Program

NASS primarily conducts applied research to improve and enhance the agency's census and survey programs. Research strives to increase the efficiency, accuracy, and quality of official estimates by improving statistical and survey methodology.

NASS's Research and Development Division is located in Washington, DC, and has about 35 permanent Federal researchers working on various statistical, methodological, and geospatial research projects. Additionally, NASS augments its research capacity by seeking input from academics through contracts or cooperative agreements.

NASS does special tabulations of its data in response to requests and makes unpublished data available in Data Labs to other government agencies and university researchers. Advanced security technology allows such access to data, which is tightly controlled and monitored to ensure all output retains the confidentiality of the farmers' individual information.

8.3. Downstream Outcomes

- **Estimation Enhancements:** NASS used model-based estimation, based on capture-recapture methods, to produce official estimates for the 2012 Census of Agriculture. Since then, NASS has expanded its use of model-based estimation techniques to improve the statistical reliability of published forecasts/estimates and to provide accurate measures of uncertainty. These methods are proving to be especially helpful when producing estimates for hard-to-survey populations, such as farmers market managers and hemp farms, which tend to be smaller, more transient, and highly dispersed compared to traditional agricultural operations in rural areas of the U.S.

Forecasts of yield for corn, soybean, wheat, and cotton yields derived from Bayesian hierarchical models are now being produced for each crop's largest producing States in parallel with NASS operational survey processes, and the results are provided to the Agricultural Statistics Board for their consideration in producing reports. Post-season county-level yield estimates for corn and soybeans are generated by integrating MODIS Land Surface Temperature (LST) products through modeling.

Small area estimation methods were advanced in three areas: county estimates for crop production, county estimates for cash rent, and agricultural wage labor rates. Small area models have been developed to improve the county-level estimates of acreage, yield, and production. After review by the field staff, models for all crops with federally mandated reporting requirements are being implemented for the 2020 crop year. Measures of uncertainty will be published with all of the resulting official statistics. Further, the rounding processes have been automated, reducing burden on the field staff who have had that responsibility. A new small area model for county-level cash rental rates is being developed based on annual data collection with the goal of implementing an improved model for 2021. A new small area model was developed for the agricultural labor program. NASS has worked collaboratively with outside consultants to develop these models.

The Decision Support System (DSS) is to being developed with the goal of providing user-friendly monitoring tools that identify crop-producing areas (within the 48 contiguous states) under potential risk due to ongoing weather conditions, allowing end-users to make timely and

informed decisions. In 2020, weekly and advanced reporting tools, which provide standardized and automated weather information for the weekly NASS Crop Progress and Condition Report, were implemented. Two new tools, the Smart Database System and Phenology and Weather Tracking tool, are being developed. The Smart Database System is an automated monitoring and notification system to alert NASS staff when observed levels of climate indicators are above or below thresholds established by users, based on the geo-area of interest (e.g., state, district or counties). The Phenology and Weather Tracking tool allows users to simulate the phenological development of a crop (soybean, corn, cotton and wheat) for any location in the U.S., while also plotting the daily values of weather variables and comparing with previous years. An additional tool, a simulation model for cotton, is under evaluation over Georgia and Texas, and should eventually lead to a crop modeling monitoring tool that facilitates the evaluation of the potential effects of extremes weather on expected crop yields.

- **Automated Stratification for Construction of Area Frame:** NASS uses its area frame both as a stand-alone frame to estimate numbers of farms and a wide variety of commodities, and as a measure of incompleteness for its list surveys–including the quinquennial Census of Agriculture. To date, new area frames for Oklahoma, Arizona, New Mexico, Georgia, South Dakota, Alabama, North Carolina, Wisconsin, Nebraska, Texas, Missouri, and Ohio have been created using a hybrid stratification approach via automatic stratification with manual editing. The new frames have more uniform strata than those based on the traditional manual stratification, leading to more precise estimates at no additional cost.

- **Sampling Frames and Web Scraping:** For most NASS surveys, the sampling frame is the NASS list frame, which is ideally a complete and up-to-date list of all U.S. agricultural operations. However, as is common for complex populations, the NASS list frame is not complete; that is, not all farms are on the list. This lack of completeness has implications for the quality of survey data and the official estimates. NASS is examining the practice of web-scraping techniques to identify farms, especially the non-traditional agricultural operations, to measure the undercoverage of the NASS list frame. NASS is working with the Multi Agency Collaboration Environment (MACE), a cross-agency effort to create data sharing partnerships across the federal government, to harvest open source information to develop web-scraped lists of agricultural operations, especially those that are not well covered by the NASS list frame, such as urban farms, operators of farmers markets, and local food producers. NASS's primary objective is to explore the feasibility of using web-scraped lists of farms to measure the undercoverage of the NASS list frame for each of the NASS surveys.

  In FY19 and FY20, NASS continued to explore the feasibility of using web-scraped lists of farms in conjunction with the NASS list frame to replace the current methodology underpinning the June Area Survey. The study was conducted in four states: Kansas, Nebraska, New York, and Pennsylvania. The initial analysis of estimates of the number of farms indicate that they may be slightly biased downward, and improved estimation methodology is being developed that should lead to improved estimates. The measures of undercoverage were accurate for livestock, but biased downward for crops. This is likely due to the use of prior year data; future efforts will

collect current year information as is currently done when using the area frame to account for undercoverage.

- **Geospatial Products:** NASS completed its 48-state Cropland Data Layer (CDL) in 2020 for the 2019 crop year, making 12 years of national CDL's available. This layer provides information on the crops planted and is useful in land cover, animal habitat, and watershed monitoring; soils utilization analysis' agribusiness planning; addressing biodiversity, crop intensity, and agricultural sustainability concerns; environmental research; and the remote sensing and GIS value-added industry. The 48-state Crop Frequency Layers for corn, soybeans, wheat, and cotton were released in 2020 for the 2019 crop season. These layers identify crop-specific planting frequency and are based on land cover information derived from the 2008 through 2019 CDLs. NASS has been working collaboratively with the USDA Agricultural Research Service (ARS) to modernize the publicly available end-of-year CDL, which is published on a web portal as CropScape, as it is moved to the USDA cloud.

  NASS, in collaboration with NASA and the USDA Agricultural Research Service (ARS), has developed a new geospatial portal, Crop Condition and Soil Moisture Application (Crop-CASMA), which is hosted at George Mason University (https://cloud.csiss.gmu.edu/Crop-CASMA). Crop-CASMA provides daily and weekly top and sub soil volumetric measurements; the measurements have been calibrated to the categorical moisture assessments presented in the weekly NASS Crop Progress and Condition Report. This product facilitates early determination of drought stress and excessive water or inundation. NASS continued to provide its 48-State

VegScape portal, which is a geospatial data service offering automated updates of vegetative condition at daily, weekly, and biweekly intervals. The VegScape and Crop-CASMA portals are in the process of integrating soil moisture and vegetation condition quantitative observations to inform on crop change dynamics.

Geospatial decision support products were derived and provided for rapid response to assess flooded areas and identify potential crop losses caused by the 12 named storms to make landfall in the contiguous U.S. during 2020. The geospatial data products were derived from remotely-sensed satellite and meteorological information obtained from NASA, European Space Agency (ESA), and National Oceanic Atmospheric Administration (NOAA). The estimates of crop and pasture hay inundation were provided to the NASS Agricultural Statistics Board for decision support. Crop inundation raster layers were shared with the USDA Operations Center Emergency Programs Division to be included in their mapping efforts. The disaster assessment reports, maps, crop inundation raster layers, metadata and a methodology report has been posted on the NASS website for public dissemination at https://www.nass.usda.gov/Research_and_Science/Disaster-Analysis/index.php. Final reports, excluding in-season crop and pasture hay estimates, were posted on the NASS web site for public use.

- **Data-Collection Enhancement for the Census of Agriculture and NASS Surveys:** NASS implemented a new, responsive, web data collection system for the 2017 Census of Agriculture. By the end of FY2019, all NASS surveys had been moved into the new system, which provides

an enhanced web experience for agricultural producers responding to NASS surveys. During FY20, NASS has added functionality to the web instrument thereby improving the user's experience. NASS worked with a contractor to develop the system for producing this responsive instrument. The goal is to continually improve the respondent's experience, reduce burden, and improve data quality.

- **Subsampling of Nonrespondents in the 2017 Census of Agriculture:** Although extensive efforts were made to increase public awareness and participation, the 2017 Census of Agriculture response in the initial phase of data collection was significantly lower than reasonably anticipated given the Census of Agriculture's history. As a result, the nonrespondent pool was too large for NASS's traditional census nonresponse follow-up method in the available timeframe. To address the nonresponse bias and remain within the resource constraints, NASS adopted a subsampling design to meet precision-related benchmarks.

- **Integrating All Available Data into NASS Estimation Processes:** Currently, the NASS Agricultural Statistics Board receives estimates and information from multiple sources for some of its programs. These include survey estimates, remote sensing estimates, and weather information. The Agricultural Statistics Board combines this information using expert opinion to produce official estimates. In FY2019, NASS initiated a pilot study in Illinois to explore a statistical modeling approach using all available data, including survey, remote sensing, administrative, weather, and precision agriculture data, to produce early season estimates of planted acreage. Remote sensing data at 10 and 30-meter resolution will be evaluated to

determine the relative value of higher resolution satellite imagery. To integrate the survey data with the other types of data, which are all geo-spatial, NASS must geo-reference its farms. The volume of the fine-resolution remote sensing data exceeds current NASS storage and computing capacity; thus, all data and the subsequent analyses must be done in a cloud environment. The goal is to address these challenges and produce early season estimates of planted acres by crop type for Illinois during the 2021 crop season. All methods used will be fully scalable to the national level.

- **Use of Previously Reported Data in NASS Surveys and the Census of Agriculture**

NASS plans to implement the use of previously reported data (PRD) for the 2022 Census of Agriculture. Usability testing conducted in FY20 identified characteristics of questions that would be suitable for PRD. For the demographics section, respondents in the usability tests found the presence of PRD too invasive of their privacy; thus, PRD for those questions will not be pursued further. Results of an experiment conducted within the 2020 September Agricultural Production Survey showed no signs of a reduction in data quality with the use of non-demographic PRD. Beta testing of a system that automates the uploading of PRD to the web instrument is to be conducted in the 2021 June Agricultural Production Survey and the 2021 Census of Agriculture Content Test. If the results indicate that PRD can be provided without harming data quality, then PRD will be used in some NASS surveys and the Census of Agriculture beginning in 2022. Contractors will facilitate the development of the PRD automation system.

- **Automated Editing and Imputation**

  Historically much of the editing and imputation for NASS surveys has been completed manually by field office staff. Based on a recommendation from an external review of NASS's editing and imputation processes, NASS has explored approaches to automating editing and imputation processes while improving data quality. Portions of the process were automated in 2020. During 2021, NASS will develop and initiate a generalized edit and imputation system for one survey with the support of contractors. The remaining surveys will be added in subsequent years.

8.4. Outreach Activities

- **Data User Input:** NASS holds an annual data-users meeting to gather input to ensure the agency statistical program is meeting the needs of our user community. The 2020 Data Users' Meeting were held virtually on April 21 and October 28, 2020. Each featured representatives from NASS as well as other USDA agencies and provided an open forum for data users to ask questions about the entire USDA statistics program. From a customer service perspective, the meeting provided an excellent opportunity for NASS to learn about data users' concerns and desires for improvements or changes to the statistics and economics programs. The virtual meeting allowed for broader participation with the usual number of 100 to 125 attendees increasing to 325 to 400 attendees.

8.5. Publications

Peer-Reviewed Scientific Publications.....9 entries

- Erciulescu, A. L.; Cruze, N. B.; Nandram, B. (2020) "Statistical Challenges in Combining Survey and Auxiliary Data to Produce Official Estimates." *Journal of Official Statistics*, vol. 36, no. 1. pp. 63-88. https://doi.org/10.2478/jos-2020-0004

- Fabbri, P.; Gaetan, C.; Sartore, L.; Dalla Libera, N. (2020). "Subsoil reconstruction in geostatistics beyond kriging: a case study in Veneto (NE, Italy)." *Hydrology*, 7(1), 15. https://www.mdpi.com/2306-5338/7/1/15/pdf.

- Johnson, D.M. (2019). "Using the Landsat archive to map crop cover history across the United States." *Remote Sensing of Environment*, vol 232, no. 111286. https://doi.org/10.1016/j.rse.2019.111286.

- Nóia Júnior, R. S.; Fraisse, C. W.; Cerbaro, V. A.; Karrei, M. A. Z.; Guindin, N. (2019). "Evaluation of the Hargreaves-Samani Methods for Estimating Reference Evapotranspiration with Ground and Gridded Weather Data Sources." Journal of Applied Engineering in Agriculture, Vol. 35(5): 823-835. ISSN 0883-8542 https://doi.org/10.13031/aea.13363.

- Olson, K.; Smyth, J.; Horwitz, R.; Keeter, S.; Lesser, V.; Marken, S.; Mathiowetz, N.; McCarthy, J.; O'Brien, E.; Opsomer, J.; Steiger, D.; Sterrett, D.; Su, J.; Suzer-Gurtekin, T;, Turakhia, C.; Wagner, J. (2020). "Transitions from Telephone Surveys to Self-Administered and Mixed-Mode Surveys: AAPOR Task Force Report." *Journal of Survey Statistics and Methodology*.

- Qian, Y.; Yang, Z.; Di, L.; Rahman, Md. S.; Tan, Z.; Xue, L.; Gao, F.; Yu, G.; Zhang, X. (2019). "Crop Growth Condition Assessment at County Scale Based on Heat-aligned Growth Stages," *Remote Sensing*, 11(20), 2439. https://doi.org/10.3390/rs11202439.

- Ridolfo, H.; Kathy O.; Jeremy B.; McCarthy, J.S. (2020). "Pre-Testing Establishment Surveys: Moving Beyond the Lab." *Survey Practice*, vol. 13 (1). https://doi.org/10.29115/SP-2020-0003.

- Sartore, L.; Wei, Y.; Abayomi, E.; Riggins, E.; Corral, G.; Bejleri, V.; and Spiegelman, C. (In press). "Modeling swine population dynamics at a finer temporal resolution." *Applied Stochastic Models in Business and Industry*.

- Zhang, C.; Di, L.; Yang, Z.; Lin, L.; and Hao, P. (2020). "AgKit4EE: A toolkit for agricultural land use modeling of the conterminous United States based on Google Earth Engine," *Environmental Modelling and Software, Vol. 129, 104694. https://doi.org/10.1016/j.envsoft.2020.104694*.

Book Chapters.....4 entries

- Corral G.R. (2020). "Investigating Selection Criteria of Constrained Cluster Analysis: Applications in Forestry." (Editors: G. Chandra, R. Nautiyal, H. Chandra). *Statistical Methods and Applications in Forestry and Environmental Sciences*. Forum for Interdisciplinary Mathematics. Springer, Singapore. https://doi.org/10.1007/978-981-15-1476-0_10.

- Dahlhamer, J. M.; Aaron M.; Heather R; Allen, A.; Brooks, D. (2020). "Exploring the Associations between Question Characteristics, Respondent Characteristics, Interviewer Performance Measures, and Survey Data Quality." (Editors: P. C. Beatty, D. Collins, L. Kaye, J-L. Padilla, G. B. Willis, and A. Wilmot). *Advances in Questionnaire Design, Development, Evaluation and Testing*, pp. 153-193, Hoboken, NJ: John Wiley & Sons.

- McCarthy, J.S. (2020). "Planning Your Multimethod Questionnaire Testing Bento Box: Complementary Methods for a Well-Balanced Test." (Editors: P. Beatty, D. Collins, L. Kaye, J.L. Padilla, G. Willis and A. Wilmot). *Advances in Questionnaire Design, Development, Evaluation and Testing*. doi:10.1002/9781119263685.ch29.

- Willimack, D.K.; McCarthy, J.S. (2020). "Obstacles and Opportunities for Experiments in Establishment Surveys Supporting Official Statistics." (Editors: P. Lavrakas, M. Traugott, C. Kennedy, A. Holbrook, E. de Leeuw and B. West). *Experimental Methods in Survey Research*. doi:10.1002/9781119083771.ch16.

Scientific Meeting Proceedings .....5 entries

- Bellow, M. (2020). “Comparison of Mixed Modeling Approaches to County-Level Crop Area Estimation Using Multiple Data Sources.” In *Proceedings of the 2020 Joint Statistical Meetings*. Philadelphia, PA: American Statistical Association

- Benecha, H.; Sartore, L.; Cruze, N. (2019). “Model-Based Crop Yield Forecasting: Covariate Selection and Related Issues”. In *Proceedings of the 2019 Joint Statistical Meetings*. Denver, CO: American Statistical Association.

- Chen, L.; Nandram, B.; Cruze, N. B. (2020). “Hierarchical Bayesian Model with Inequality Constraints for County Estimates.” In *Proceedings of the 2020 Joint Statistical Meetings*. Philadelphia, PA: American Statistical Association.

- Cruze, N.B.; Chen, L.; Guindin, N.; and Nandram, B. (2020). “Dancing Distributions: Developing a Better Understanding of County-Level Crop Yield from Posterior Summaries.” In *Proceedings of the 2020 Joint Statistical Meetings*. Philadelphia, PA: American Statistical Association.

- Zhang, C.; Yang, Z.; Di, L.; Lin, L. (2019) “Refinement of Historical Cropland Data Layer Based on Deep Learning Approach.” Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-3/W11, 161–164, Pecora 21/ISRSE 38, Baltimore, MD, October 6-11, 2019. https://doi.org/10.5194/isprs-archives-XLII-3-W11-161-2020.

Software Published……0 entries

Trade Journal Publications.....0 entries

9.0. National Institute of Food and Agriculture (NIFA)

9.1. Mission and Vision Statements

NIFA's mission is to "invest in and advance agricultural research, education, and extension to solve societal challenges." NIFA's approaches its mission with the following vision, "Catalyze transformative discoveries, education, and engagement to address agricultural challenges."

9.2. Nature and Structure of Research Program

NIFA's two key mechanisms for accomplishing its mission are:

- Federal assistance - NIFA provides annual capacity grants to land-grant universities and competitively granted funds to researchers in land-grant universities, other universities, and other partner organizations; and

- National program leadership - NIFA helps states identify and meet research, extension, and education priorities in areas of public concern that affect agricultural producers, small business owners, youth and families, and others.

NIFA collaborates or has formal working partnerships with many institutions, associations and members of the research and extension communities. Our key partners are the institutions of higher learning

making up the Land-Grant University System. NIFA also offers multiple grants in research, education, and extension that benefit Minority Service Institutions. Partnerships among land-grant and non-land-grant institutions and organizations strengthen program developments and resources. These partnerships have resulted in innovative research, education, and extension nutrition and health-enhancing programs that are culturally appropriate. NIFApartners with other federal agencies, within and beyond USDA; non-profit associations; professional societies; commodity groups and grower associations; multistate research committees; private industry; citizen groups; foundations; regional centers; the military; task forces; and other groups.

NIFA and its partners focus on critical issues affecting people, the environment, rural and urban communities, all of which serve to enhance the nation's future. The advanced research and educational technologies that NIFA supports empower people and communities to solve problems and improve their lives.

Among the programs NIFA leads, many are currently focusing efforts on the following societal challenges through pursuing the USDA Strategic Goals, the USDA Science Blueprint: A Roadmap for USDA Science from 2020 to 2025, and the Agriculture Innovation Agenda. Primary areas of focus reflected through Technology Transfer are:

- Advance our ability to provide global food security through increased productivity and profitability in American agriculture.

- Create a resilient and environmentally sustainable agricultural system responsive to climate change.

- Catalyze value-added innovations in agriculture.

- Ensure the availability of affordable, nutritious, and safe food and increase the public's knowledge of and trust in their food supply and nutritional needs.

- Implement an innovation strategy that aligns and synchronizes public- and private-sector research.

NIFA accomplishes these goals not only through their research and higher education programs, but also through an extensive network of state, regional, and county extension offices in every U.S. state and territory. These offices have educators and other staff who respond to public inquiries and conduct informal, noncredit workshops and other educational events. Extension education for all citizens is also provided nationally online through eXtension.org.

Moreover, with support from more than 500,000 volunteers, 4-H - USDA's 118-year-old youth development program administered through NIFA, engages more than 6 million young people every year and teaches them life skills through hands-on learning and leadership activities.

9.3. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)

Applicants or recipients of NIFA grants that support basic research and integrated projects are encouraged to explore potential commercialization through the Small Business Innovation Research (SBIR) program. Conversely, small business owners or other grant recipients are encouraged to use NIFA-funded foundational research programs to enhance innovation and competitiveness in their commercial operations.

Each land-grant university funded by NIFA has a university technology transfer office to promote, support and improve technology transfer from academic and nonprofit institutions. They often manage and license innovations derived from research at their universities (including research funded by NIFA) and are a good source to link small businesses with university faculty. Moreover, the Cooperative Extension System Offices are a nationwide, non-credit educational network. These offices are staffed by one or more experts who provide useful, practical, and research-based information to agricultural producers, small business owners, youth, consumers, and others in rural areas and communities of all sizes.

9.4. Strengthening Current Activities and New Initiatives

The National Institute of Food and Agriculture (NIFA) administers the USDA Small Business Innovation Research (SBIR) program. In FY 2020, NIFA promoted SBIR funding opportunities to USDA intramural research Cooperative Research and Development Agreement (CRADA) partners through a partnership between NIFA's SBIR program and the Agricultural Research Service (ARS) Office of Technology Transfer (OTT).

Through this partnership with ARS, NIFA informs potential SBIR applicants of partnership possibilities and benefits of working with ARS scientists. If ARS and a small business identify an opportunity to partner together, the small business would submit an SBIR application and would address this partnership. The partnership is generally developed under a CRADA or through a licensing agreement between ARS and the small business. NIFA in turn uses the knowledge of an ARS CRADA or license as a tie-breaker in the application selection process. Some of the benefits a small business can employ when partnering with ARS is joint intellectual property potential. ARS files the patent applications for CRADA partners and only charges the partner for filing fees, and patent application fees. The patent prosecution completed by registered USDA patent agents is provided free of charge saving small businesses substantial costs. In FY20, USDA SBIR awarded 8 CRADA proposals across the program's 10 topic areas.

Since FY2018, the Agriculture and Food Research Initiative (AFRI) Sustainable Agricultural Systems Program has encouraged partnerships in research and implementation through research, extension and education integration in order to help transform the US food and agricultural systems. During the first two years of the program, 17 projects were awarded $170 M over 5 years to promote the sustainable supply of abundant, affordable, safe, nutritious, and accessible food and other agricultural products, while enhancing economic opportunities and improving the long-term health and well-being of all Americans. A significant objective of the program is to facilitate the translation of foundational research into applied research and product development that provides impact and adoption of technology solutions. Five of these projects have collaborations with organizations involved in adoption and or commercialization. These projects address challenges of sustaining beef production in the western

United States; transforming shellfish aquaculture; improving environmental quality and rural prosperity through deploying perennial grain crop through supply chains into cropping systems; increasing agricultural productivity and profitability by reducing input costs and environmental stresses; developing, deploying and scale-up of a renewable natural gas and associated bioproducts to provide an additional sustainable revenue.

9.5. Response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Business

USDA 27: New Metrics (beginning FY 2014) on NIFA outcomes:

Efforts to develop procedures for requesting information from NIFA awardees are in progress. A survey of past SBIR Phase II winners from 1994 through 2015 was conducted in 2018. Responses are being analyzed. The survey collected information on: 1) number of new jobs created by a small business as the result of receiving SBIR grant funds; 2) increase in sales of technology or services developed by a small business as the result of receiving SBIR grant funds; and 3) sale to other businesses of licenses to technology developed by a small business as the result of receiving SBIR grant funds.

The data on the patents issued based upon Competitive NIFA Funding has been collected for FY2020 and is now being reported (see Table 1). Patents cover a broad scope of agriculture innovations inclusive of methods, processes, instrumentation, enabling technologies, plant varieties and hybrids, animal therapeutics, and diagnostics.

Table 1. Patents Issued in FY2020 based upon Competitive NIFA Funding.

Institution Name	Award Number	Patent Number	Issue Date	Invention Description
PENNSYLVANIA STATE UNIVERSITY	2008-51180-19561	10448578	10/22/2019	METHODS FOR SELECTIVE TREE FRUIT THINNING USING MECHANICALLY CONTROLLED BRUSHES
PENNSYLVANIA STATE UNIVERSITY	NA/PEN04511	10456068	10/29/2019	DEVICE FOR OBTAINING SMALL VOLUMES OF FLUID FROM ANIMALS
BAYLOR COLLEGE OF MEDICINE	3092-51000-055-50S	10470446	11/12/2019	EPIGENETIC ENGINEERING TO STUDY THE ROLE OF ABERRANT DNA METHYLATION IN DISEASE
UNIVERSITY OF MISSOURI-COLUMBIA	2015-67015-23231	10485584	11/26/2019	NOVEL SUPPLEMENT FOR CULTIVATION OF MAMMALIAN EMBRYOS
UNIVERSITY OF NEBRASKA LINCOLN	2014-31100-06031	10501766	12/10/2019	SYSTEM FOR OPTIMIZING FED-BATCH HYDROLYSIS OF BIOMASS
UNIVERSITY OF WISCONSIN-MADISON	14-CRHF-0-6055	10544389	1/28/2020	GLOBAL GENE REGULATORS (GGR) AS VACCINE CANDIDATES AGAINST PARATUBERCULOSIS.
MICHIGAN STATE UNIVERSITY	2016-34141-25707	PV201800188	1/29/2020	MSW485-2 CHIPPING POTATO
NORTH DAKOTA STATE UNIVERSITY	2006-31100-06038	PV201800134	1/29/2020	'ND RIVELAND' DURUM WHEAT (D09690)
PENNSYLVANIA STATE UNIVERSITY	NA/PEN04436	10550353	2/4/2020	MULTI-SURFACTANT SYSTEMS
PENNSYLVANIA STATE UNIVERSITY	2007-35318-18350	10563216	2/18/2020	TARGETED DELIVERY SYSTEM FOR CROP SPECIES

UNIVERSITY OF WISCONSIN-MADISON	2009-55503-05206	10568831	2/25/2020	METHOD TO ENHANCE SWALLOWING SAFETY AND APPEAL OF BEVERAGES FOR TREATING DYSPHAGIA BASED ON RHEOLOGICAL AND SENSORY PARAMETERS
UNIVERSITY OF WISCONSIN-MADISON	14-CRHF-0-6055	10578598	3/3/2020	NANOREACTORS AS THERMAL HISTORY INDICATORS
PENNSYLVANIA STATE UNIVERSITY	NA/PEN01607	10598575	3/24/2020	A SIZE TUNABLE ENRICHMENT PLATFORM FOR CAPTURING NANO PARTICLES IN A FLUID
NORTH DAKOTA STATE UNIVERSITY	2003-31100-06038	PV201800047	3/27/2020	'ND EAGLE' (LC07ND055E) LENTIL
NORTH DAKOTA STATE UNIVERSITY	2007-31100-06038	PV201800126	3/27/2020	'ND STUTSMAN' SOYBEAN (ND10-3067)
NORTH DAKOTA STATE UNIVERSITY	2010-31100-06038	PV201800012	3/27/2020	'ND17009GT' SOYBEAN (ND12-21598)
OKLAHOMA STATE UNIVERSITY	2009-34447-19951	10640792	5/5/2020	FERMENTATION CONTROL FOR OPTIMIZATION OF SYNGAS UTILIZATION
COLORADO STATE UNIVERSITY	2017-34141-27336	PV0006191	5/13/2020	AAC BROOKVILLE
NORTH DAKOTA STATE UNIVERSITY	2008-31100-06038	PV201700085	5/18/2020	'ND PALOMINO' (SF-103-8) PINTO BEAN
NORTH DAKOTA STATE UNIVERSITY	2003-31100-06038	PV201800167	5/18/2020	'ND DYLAN' WINTER RYE (FORMERLY DR02)
NORTH DAKOTA STATE UNIVERSITY	2008-31100-06038	PV201800124	5/18/2020	'ND BENSON' SOYBEAN (ND10-3464)
NORTH DAKOTA STATE UNIVERSITY	2006-31100-06038	PV201800133	5/18/2020	'ND GRANO' DURUM WHEAT (D09557)

UNIVERSITY OF WISCONSIN-MADISON	05-CRHF-0-6055	10676793	6/9/2020	DAIRY CATTLE BREEDING FOR IMPROVED MILK PRODUCTION TRAITS IN CATTLE
UNIVERSITY OF WISCONSIN-MADISON	14-CRHF-0-6055	10676392	6/9/2020	TRANSPARENT CONDUCTING FILMS CONTAINING SINGLE-WALLED CARBON NANOTUBES DISPERSED IN AN AZO DYE
UNIVERSITY OF WISCONSIN-MADISON	18-CRHF-0-6055	10675241	6/9/2020	COMPOSITIONS CONTAINING PREEN OIL AND METHODS OF USE THEREOF
OHIO STATE UNIVERSITY	2013-67015-20476	10682314	6/16/2020	NANOPARTICLE ENTRAPPED INFLUENZA VIRUS VACCINE DELIVERY SYSTEM
NORTH DAKOTA STATE UNIVERSITY*	2006-31100-06038	PV2900186	6/24/2020	'ND HAMMOND' FLAX LINE (FORMERLY NDFB10)
PENNSYLVANIA STATE UNIVERSITY	2008-34437-19335	10697014	6/30/2020	GENOMIC REGIONS WITH EPIGENETIC VARIATION THAT CONTRIBUTE TO PHENOTYPIC DIFFERENCES IN CATTLE
UNIVERSITY OF MINNESOTA	2014-67009-22305	10709151	7/14/2020	LOW FIBER PENNYCRESS MEAL AND METHODS OF MAKING
UNIVERSITY OF WISCONSIN-MADISON	2008-55620-19132	10729758	8/4/2020	BROADLY REACTIVE MOSAIC PEPTIDE INFLUENZA VACCINE
PENNSYLVANIA STATE UNIVERSITY	NA/PEN04224	10737958	8/11/2020	ANIMAL MANURE TREATMENT SYSTEM
UNIVERSITY OF WISCONSIN-MADISON	2007-35205-17884	10745757	8/18/2020	COMPOSITIONS AND METHODS FOR DETERMINING LIKELIHOOD OF AN INCREASED SUSCEPTIBILITY TO CONTRACT JOHNE'S DISEASE

UNIVERSITY OF WISCONSIN-MADISON	2004-35503-14839	10765135	9/8/2020	PRODUCTION OF PROTEIN-POLYSACCHARIDE CONJUGATES

USDA 28: Partnerships with ARS and the Animal and Plant Health Inspection Service (APHIS) at USDA on the National Plant Diagnostic Network, and the National Animal Health Laboratory Network

There are two goals for NIFA in this area.

(1) Develop competitive funding opportunities to include ARS scientists in the development of diagnostic assays and validation protocols that are needed to support APHIS regulatory surveillance efforts for foreign and emerging plant and animal diseases.

ARS scientists are eligible for competitive grants from AFRI. In FY2021 and FY2022 (and in previous years), the AFRI A1221 (Diseases of Agricultural Animals) program includes a priority on disease prevention and control, including vaccines; reverse vaccinology; and diagnostics (for endemic diseases only). The AFRI A1181 (Tactical Sciences for Agricultural Biosecurity) program supports diagnostics for transboundary/foreign and emerging/re-emerging diseases. For diagnostic tests, applicants must provide a validation plan.

(2) Coordinate APHIS regulatory and ARS research efforts with relevant components of the Cooperative Extension Service in order to better identify producer needs and the transfer of relevant technology.

For nearly 20 years, NIFA and ARS have collaborated to conduct stakeholder workshops at least every five years as part of the ARS five-year review of ARS National Programs. In FY2020, ARS conducted a five-year review of the National Program (NP)103 on Animal Health. NIFA participated in this process to ensure that land-grant university faculty were given opportunities to complete the online survey. More than 500 stakeholders provided comments. In FY2021, ARS is conducting a five-year review of the ARS NP101 Food Animal Production program. ARS will conduct an online survey and NIFA will ensure that faculty at land-grant universities have opportunities to complete the survey. In addition, in January 2021 ARS and NIFA administrators will co-lead several webinars to collect stakeholder input that will inform priorities for NIFA competitive grant programs. NIFA will use stakeholder input from these coordinated activities with ARS to inform priorities for future NIFA competitive grant programs, including programs that will address the needs of producers and programs that provide funding opportunities for Extension activities to transfer knowledge and technology developed from research projects to producers. With specific regard to aquatic animals, APHIS, ARS, and NIFA coordinate the NSTC Joint Subcommittee on Aquaculture. Within this subcommittee, there is an Animal Health working group.

Another example of a coordination is with the National Plant Protection Laboratory Accreditation Program (NPPLAP) which evaluates laboratories that use molecular diagnostics to support APHIS PPQ programs to ensure their capability to make accurate diagnostic determinations for regulatory purposes. The NPPLAP ensures diagnostic capacity for PPQ and establishes a state of readiness to support PPQ emergency programs. To ensure lab capability, NPPLAP accredits USDA regulatory labs, laboratories within the National Plant Diagnostic Network (NPDN), and state agricultural department laboratories to validate proficiency throughout dispersed laboratory network. Additional partnerships include the NPDN and the National Clean Plant Network (NCPN). The NCPN operates under the auspices of three USDA agencies: APHIS, ARS, and NIFA.

9.6. Downstream Outcomes

Jun Innovations Inc. has made advancements to the commercialization of supercooling technology for subzero nonfreezing preservation of fresh foods. Within the food industry and its associated research, the term supercooling has been used to describe an area of study in which researchers attempt to bring food products below their natural freezing temperatures while preventing ice formation. The project developed an early commercial supercooling device to demonstrate the feasibility of moderate bulk food storage under supercooled conditions. In addition, the company leveraged a sub-contractor, Dr. Soojin Jun's Food Processing Lab at University of Hawaii, for continuation of supercooling research. Technology was implemented for preserving diverse foods within a single

chamber due to the complexity involved with different characteristics of foods and balancing of electrical power delivered to each food item. The modified electrical control unit enabled the company to set a voltage at which a balance occurred between beef and tuna based on their impedance to the PEF signal, allowing supercooling at the same temperature.

Accelerated Ag Technologies (AAT, dba PowerPollen®) developed protocols for large scale conditioning and transport of maize pollen suitable for field applications. The company collaborated with agricultural manufacturing firms to construct and deploy commercial-scale pollen collectors and PowerPollen® applicators for parent seed fields and commercial hybrid seed fields. New technology developed enabled the conditioning, preservation and storage of massive amounts of maize pollen. This novel technology generated new intellectual property now listed under patents US20170238535A1 and US20190008144A1. From 2018-20, AAT deployed PowerPollen® across several commercial customers. The company projects a broader commercialization in 2021 now with a long-term commercial agreement and is expected to execute two long-term commercial agreements with other major seed companies by Q1 2021, driven by the technology innovation.

VRM Labs, Inc. is developing natural biodegradable flocculants. Flocculants are substances, which destabilize colloidal suspensions and promote the clumping and settling of the suspended particles. Among the most important applications of flocculants is treatment of agricultural wastewaters, such as the wastewaters generated in livestock slaughter and processing plants, rendering plants, etc. Flocculants are also directly applied to soil to prevent erosion in agricultural and construction areas.

Most of the currently used flocculants are synthetic and their application in large scale agriculturally-related processes is becoming a growing concern for consumers, public, and regulatory entities due to their lack of biodegradability and potential toxicity of accumulated contaminants. While these synthetic flocculants are attractive due to their high effectiveness and low cost, there is growing concern about the environmental and health impacts of these substances. Dr. Garcia and co-workers, from a USDA/ARS lab, recently discovered that hemoglobin can function as a powerful biodegradable flocculant suitable for wastewater recovery. Through technology development and transfer, work is ongoing to develop and commercialize a cost-efficient biodegradable hemoglobin-based flocculant.

Diversified Technologies, Inc. (DTI) worked with the Arizona Center for Algae Technology and Innovation (AzCATI) at Arizona State University (ASU) on the application of Pulsed Electric Field (PEF) processing on the growth and extraction of microalgae and microalgae products. PEF processing uses short, high voltage electrical pulses to break cellular membranes. The project addressed a priority area by utilizing energy efficient PEF technology to reduce costs and enhance yields in aquaculture. DTI and AzCATI were able to validate the value of PEF to algal product extraction and predator control. This paves the way for commercial introduction of PEF into the algal processing and cultivation market.

The Julia Group completed four products that served community needs through computer-based interventions for Rural Youth impacted by substance abuse. As a result of social distancing measures taken to reduce the spread of Coronavirus, the interest in educational software and telemedicine, including mental health applications, rose dramatically in 2020. Usability was not a barrier in terms of

understanding how to use the application or being able to play except in a small number of cases where users had significant learning or cognitive disabilities that resulted in reading below the third-grade level. A study of retention and attendance of 47 participants in grades five through twelve had a course completion rate of 96% with average daily attendance over 90%. Technology developed under this proposal has three types of commercial application; as components within a larger institutional sale of a catalog of software, code libraries usable in a variety of software products and as a standalone product for education and assessment of at-risk youth

Precision Combustion, Inc. developed a compact, efficient and economic soil steam disinfestation. Soil disinfestation removes soil pathogens, pests and weeds that limit crop health and production facilitating less dependence on chemical fumigants such as methyl bromide and chloropicrin currently used for this purpose in open fields, especially for high value annual plants such as strawberries and other berries. Other potential applications and markets include commercial flowers and golf courses. Precision Combustion, Inc. completed design and engineering for the device.

Ripple Rock Fish Farms, LLC transfers generations of aquaculture experience through support packages. Knowledge transfer occurs by system optimization important for small farmers to be successful from the very beginning of his/her aquaculture experience by developing a balance of engineering, biological, chemical, mechanical and business skills in the form of written manuals, design plans, business guidance, and training programs. Ripple Rock Fish Farms technology advantage reduces the growing season for aquaculture farmers by over 50%.

Westscape Wholesale Nursery LLP developed a novel, proprietary formulation for control of the annual invasive species, cheatgrass (*Bromus tectorum* L.) and its relatives, and to simultaneously promote the growth of desirable perennial grass species. Cheatgrass is also the driving component behind the catastrophic wildfires occurring with increasing frequency and magnitude across the Intermountain and Western region. Westscape has effectively and scientifically demonstrated that it could in fact control the germination and growth of these invasive species in small greenhouse and field studies in Montana. The primary active ingredient in the product line are naturally occurring, elemental materials considered broadly safe for humans and animals and can provide land managers with a safer alternative to the industry-standard synthetic formulations currently being used to control cheatgrass. These products are specifically designed for small acreage (farm, ranch, pasture) use. These products represent a paradigm shift in how cheatgrass reclamation is managed, and will reduce herbicide usage and overall reclamation costs, allowing more acreage to be treated, while simultaneously enhancing the establishment of native reclamation species over current practices.

Montana BioAgriculture Inc. (MBAI) developed and demonstrated at pilot scale an integrated biological process for producing multiple bio-products from barley. Researchers with MBAI developed an enzymatic fractionation process to produce 60% protein concentrates from grains with the primary market as a protein ingredient in aquaculture feeds. Although the process can use multiple grains and oil seeds, barley is the preferred feedstock for product quality and process economics. It also successfully developed production of these co-products at pilot scale. The project led to a technology license and initiation of project to construct a commercial production plant.

Keystone Tower Systems has developed and validated segmented flanges for large diameter wind turbine towers. Wind energy technology is a clean, low cost source of electricity where wind resources are available. Keystone's flange fit-up system, along with the weld procedures and geometries validated by project testing, is a key enabling technology for on-site production of tall wind towers. In addition, the system reduces the time required for and increases quality of attaching all flanges, even for smaller towers with full-ring flanges, and will have commercial applications in production of standard wind towers and large, flanged pipes (e.g., water pipes) as well. Overall, this technology promises to enable greatly increased deployment of wind energy, by reducing costs and enabling economical wind production in all regions of the U.S.

Dr. Randall Phebus, professor of food safety and his team at KSU are researching protection of meat and poultry processing industry workers, carving out answers to how COVID-19 survives in meat processing plants. The pandemic situation across the country has sparked rapid response research at Kansas State University's (KSU) Biosecurity Research Institute. It's a location at Kansas State that houses high-level research with animals, plants and the food system where researchers are trying to carve out answers. The containment facilities there are now being used to learn more about COVID-19 and how it can be transmitted in various environmental situations.

Texas A&M AgriLife researchers have made a discovery that will help combat fastidious pathogens, which cost U.S. agriculture billions of dollars annually. For the past few years, Kranthi Mandadi, Ph.D., a Texas A&M AgriLife Research scientist, and his colleagues have been developing new biological technologies to fight fastidious or "unculturable" pathogens. Their work, "Plant hairy roots enable high

throughput identification of new antimicrobials against *Candidatus Liberibacter* spp," was recently published in Nature Communications.

University of Arizona Professor of Plant Sciences Eliot Herman has spent his career studying why plants trigger allergic reactions and how to reduce the chance of them being triggered. About 7% of children and 2% of adults in the U.S. suffer from some kind of food allergy. These allergies cost $25 billion in health care each year. Herman worked to understand why this protein is so aggravating and how we can reduce it in the crop. Herman worked with a research team that bred pigs that are extra sensitive to soybeans, used to test new, non-GMO, low-allergen soybeans to determine if they are safe enough for allergic individuals.

The Juntos Sustainable Community Project is a 4-H life skills, technology enhanced, dropout prevention and college preparation program with Latinx youth and their parents in North Carolina and Idaho. The project has many goals from increasing academic success by various mechanisms to increasing higher education matriculation and increasing the use of technology for workforce skills necessary for the 21st century digital economy. Reports indicate 65% of youth feel confident in school; 59% reported communicating better with teachers and other school staff. As well, 78% of students took responsibility/steps for improving their grade. Fifty-six (56) percent of students improved attendance while in Juntos.

At Purdue University in Indiana, the Extension Disaster Education Network (EDEN) has developed *Extension and Mental Health Resiliency During Times of Disaster and Recovery,* a seven-part

series published to assist Extension Professionals in dealing with the vicarious trauma resulting from working with stakeholders following a disaster. The document series is under final peer-review.

The Southern Rural Development Center, based at Mississippi State University, and the National Digital Extension Education Team partnered with the National 4-H Council, Microsoft and Georgia 4-H to train 1,000 youth Digital Ambassadors and adult leaders to address the digital divide across 16 states and 91 communities through the 4-H Tech Changemakers program. Led by local youth/adult teams, communities benefited from learning important digital skills designed to help them thrive in a digital economy and benefit from high-speed connectivity.

9.7. Outreach Activities

- In FY2020, a number of NIFA's SBIR staff attended virtual SBIR Conferences, and regional workshops with formal presentations on the USDA SBIR program. Additionally, the USDA SBIR program staff conducted one-on-one virtual meetings with over 700 entrepreneurs and discussed both SBIR opportunities and Technology Transfer opportunities. The Staff from the USDA SBIR program participated in the Southern California Regional SBIR/STTR Conference, the New Mexico State University AgSpring Accelerator, and the BBCetc SBIR Training with Federal Officers focused on underserved and rural regions specifically in Michigan, Oklahoma, Kansas, Nebraska, South Dakota and North Dakota.

- Over the course of FY 2020, the USDA SBIR program in conjunction with the Small Business Administration (SBA) had staff participate in 2 virtual SBIR Regional Road Tours. The focus of these tours and regional conferences were to conduct outreach to potential small businesses found in underrepresented states. In each case a presentation was provided on the USDA SBIR program and included information and opportunities for Technology Transfer. The road tours provided outreach to over 800 attendees in total, provided on average 30-35 one-on-one meetings with small business entrepreneurs at each meeting, and covered the following states Indiana, Nebraska, Missouri, Illinois, Mississippi, Texas, Oklahoma, Arkansas, and Louisiana.

10.0. The Natural Resource Conservation Service (NRCS)

Table 1. Performance measures deemed important by the NRCS.

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Soils Research and Technology Transfer					
Number of publications by scientific or technology transfer staff				25	37
Number of talks, conference attendances, speeches, webinars (i.e. other forms of outreach) on Federal technology transfer			55	74	161
Number of new alliances, (e.g., partnership intermediary agreements, memorandums of understanding)	3	3	4	3	11
Plant Material Centers (PMC)					
Number of technical publications	146	122	134	86	183
Number of talks and presentations to transfer plant materials information	97	86	68	72	47
Number of participants (internal and external) attending plant materials technology training sessions	1986	2467	1515	3187	1086
Number of tours & field days	59	38	46	31	10
Number of new conservation plant releases from PMCs	4	3	1	2	6
Conservation Practice Standards					
Development or revision of conservation practice standards	25	7	21	9	58
Conservation Engineering					
Number of talks, conference					2

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
attendances, speeches, webinars (i.e., other forms of outreach) on Federal technology transfer					
Number of new alliances, (e.g., partnership intermediary agreements, memorandum of understanding)					1
National Technology Support Centers					
Number of publications by scientific or technology transfer staff					2
Number of talks, conference attendances, speeches, webinars (i.e. other forms of outreach) on Federal technology transfer					2
Science and Technology Training Library					
Number of new webinars hosted					35
Number of participants who viewed webinars and training in the Training Library					9,884
Number of continuing education units					2,176
Soil Health					
Number of publications by scientific or technology transfer staff					117
Number of talks, conference attendances, speeches, webinars (i.e. other forms of outreach) on Federal technology transfer					204
Number of participants who viewed webinars					5,203
Number of demonstrations & field days					184
Snow Survey and Water Supply Forecasting					
Number of publications by	3	4	3	5	4

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
scientific or technology transfer staff					
Number of talks, conference attendances, speeches, webinars (i.e. other forms of outreach) on Federal technology transfer	7	8	9	7	9
ppqppqer of new alliances, (e.g., partnership intermediary agreements, Memorandum of Understanding)	21	21	25	22	20
Number of demonstrations & field days	56	50	52	53	40
Soil Climate Analysis Network (SCAN) and Tribal SCAN installations	0	0	12	12	1
SNOTEL and Snolite installations	6	6	18	8	8
Snow surveys	1586	1588	1572	1579	857
Number of forecast points	600	600	600	600	600
Conservation Innovation Grants (CIG)					
CIGs awarded to non-Federal entities for technology demonstration and transfer	84	110	81	96	38[1]

[1]Numbers of State awards for the fiscal year are reported after the agency submission of this report. Reported numbers only include the number of national awards in the fiscal year.

SUCCESS STORIES DEMONSTRATING DOWNSTREAM OUTCOMES FROM TECHNOLOGY TRANSFER ACTIVITIES

10.1. Mission Statement

The Natural Resources Conservation Service (NRCS) mission is to deliver science-based conservation solutions so agricultural producers can protect natural resources and feed a growing world. NRCS conservation experts help landowners develop conservation plans and often provide opportunities for financial assistance to implement conservation practices. To carry out this mission on a broad scale (NRCS's discretionary and mandatory annual budget is approximately $4 billion), NRCS has become perhaps the country's premier agency for transfer of applied natural resources conservation approaches and technology. NRCS maintains 170 National Conservation Practice Standards (CPSs). These standards and supporting documents are NRCS's principle vehicle for transferring the latest science and technology directly to America's farmers and ranchers.

10.2. Nature and Structure of Programs

Once NRCS conservation planners identify resource needs on private farms and ranches, the agency works closely with the Agricultural Research Service (ARS) and numerous universities to develop and fine tune the science and technologies needed to help farmers conserve, protect, and enhance their natural resources. NRCS in-house research and technology development programs include the Soil and Plant Science Division and the Plant Materials Centers. NRCS also conducts conservation field trials to

strengthen NRCS technology when formal research is not available. As appropriate, NRCS conducts these trials on working farms and ranches in cooperation with other agencies and organizations. A field trial is a study designed to examine the adequacy or adaptability of a conservation practice, technology, procedure, or material. Field trials also introduce promising conservation practices or technologies into areas where they are not now accepted as a solution to a local soil, water, or related natural resource problem or condition. Field trials can be useful to transfer technology, to update the local technical guide, or identify the need for formal research.

10.3. Soils Research and Technology Transfer

The NRCS Soil and Plant Science Division (SPSD) is authorized by the Secretary of Agriculture to conduct research on the use and behavior of soils to facilitate soil classifications and distribution of information through the Web Soil Survey and other vehicles of data dissemination. Below are some current research and technology transfer efforts that are currently underway.

Alternative Crops in Colombia – Cacao for Peace

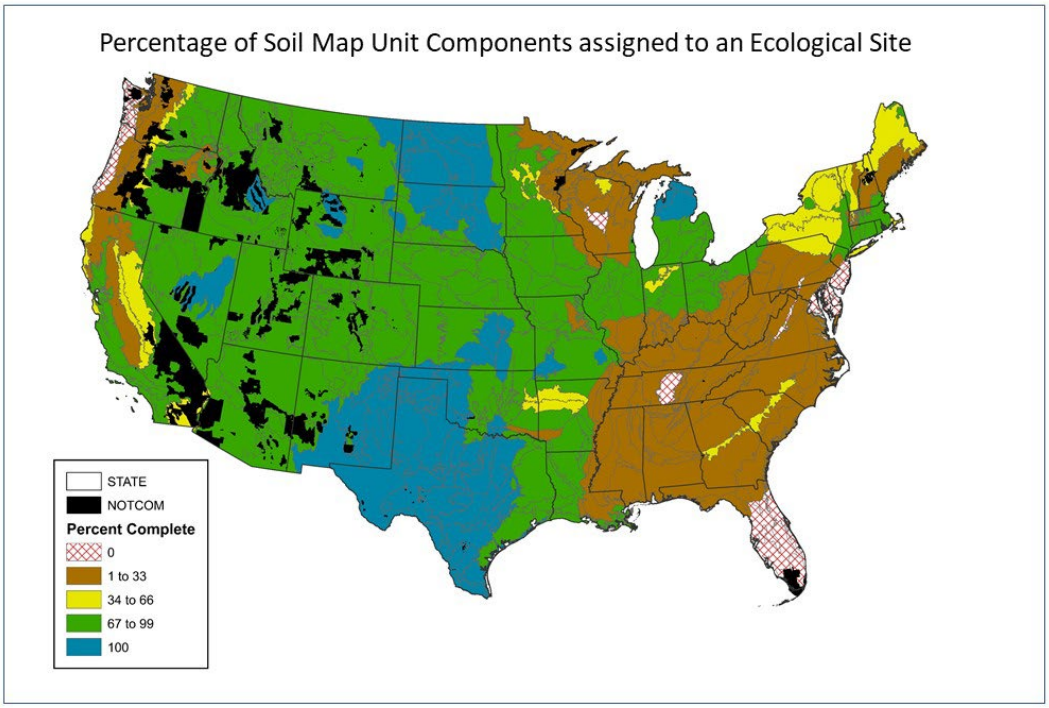
The SPSD collaborated with the U.S. Agency for International Development through the USDA Foreign Agricultural Service (FAS) and Pennsylvania State University International Center for Tropical Agriculture (CIAT) to develop and implement a pilot project to build capacity through public-private partnerships to increase quality cacao production in the Sierra Nevada de Santa Marta region in Colombia, South America. NRCS's role is to build capacity by providing technical assistance in

traditional digital soil mapping at resolutions suitable for management at the farm level. Higher resolution soil maps will better delineate areas suitable for cacao production and will be used to promote natural resources conservation and land use sustainability to meet established soil and food security goals. NRCS staff applied established digital soil mapping practices and standards, in collaboration with CIAT and local Colombian scientists and growers, to develop higher resolution soil maps for project focus areas and refine the cacao suitability assessments. Due to concerns about high cadmium in cacao from the region, NRCS and partners also investigated the spatial and vertical distribution of cadmium in soils within the project area. Through these efforts, NRCS conducted digital soil mapping and soil erosion modeling in the spring of 2020 using field Colombia-specific soils and weather information collected in the spring of 2019. This will help build local capacity in digital and traditional soil mapping technologies. Field observations as well as laboratory data were used to create high resolution maps and develop a soils information system platform with interpretations that met the needs of individual farmers, landowners, policy makers, and other interested parties.

Ecological Site Information

Ecological sites (ES) are interpretive groups of soil survey map units. Each ES has a unique ecological site description (ESD) that contains information that resource managers can use to verify the ES for their area of interest, conduct inventories of soil properties, vegetation dynamics and land use/management interpretations for conservation planning. All ESDs are stored and managed in a common platform, the Ecological Dynamics Interpretive Tool (EDIT). EDIT information is available at https://edit.jornada.nmsu.edu/.

At the end of Fiscal Year 2020, significant progress toward completing the Provisional Ecological Site Initiative had been accomplished with many Major Land Resource Areas (MLRAs) ending with a range of 67 to 100 percent coverage. Future work in the western two-thirds of the U.S. will focus on certain areas in California and the Pacific Northwest that either have a few or no Provisional Ecological Sites. In the eastern one-third of the country, where there has not been a history of Ecological Site use, few areas are considered completed, but most areas have made some progress (brown and yellow). This effort will continue in 2021.



During 2020, database development was focused on connecting soil properties housed in the National Soils Information System (NASIS) to the appropriate ESDs in EDIT to allow for analysis and

exploration through the public-facing data delivery websites of Web Soil Survey and SoilWeb. Currently, NASIS x EDIT connections are awaiting certification by the Farm Production and Conservation (FPAC) Business Center (FBC) before being deployed. The NRCS planning process was introduced into EDIT in 2020 via the use of Resource Concerns dropdown menus, connections to the National Handbook of Conservation Practices, and an interactive tool to include rangeland health worksheets.

In 2020, a new MOU with the U.S. Forest Service (FS) was negotiated to better define the complimentary roles of ESs and the Terrestrial Ecosystem Unit Inventory (the FS ecological inventory). A collaboration with the FS research branch has commenced to develop a machine learning approach to state-and-transition model development. Collaboration with Bureau of Land Management (BLM) also advanced significantly in 2020. The BLM National Training Center committed to funding a position at the Jornada Experimental Range to integrate the BLM Assessment, Inventory and Monitoring data into EDIT via the Landscape Commons Tool. This allows site specific information to be linked to the appropriate ESD and updated as new point information is acquired.

PLANTS Database

Established in 1990, the PLANTS (Plant List of Accepted Nomenclature, Taxonomy & Symbols) database and website (https://plants.sc.egov.usda.gov) are an international standard for plant information. PLANTS serves many agencies throughout the Federal Government, as well as State and local agencies, private organizations, the general public, and global users that make up its over 2.5

million users who record approximately 4 million sessions per year. PLANTS provide data for approximately 35,000 plant species occurring in the United States and its possessions. Plant data include scientific names, geographic distribution, photographs and illustrations, scientific references, legal status information (endangered and threatened, invasive, noxious, wetland), and other characteristics important for conservation planning.

NRCS National Soil Survey Center

The SPSD National Soil Survey Center (NSSC) in Lincoln, Nebraska, is a world-renowned facility for soils research, soil interpretation development and soil data development, as well as information delivery, soil policy and procedure development, and extensive training. One section of the NSSC supports the Web Soil Survey, which delivers soils data and interactive soils information to over 450,000 people annually. The visitors to Web Soil Survey accumulated 2.5 million views of the wide arrays of services including preparing customized soil reports and direct downloads of soils data. The NSSC also houses the Kellogg Soil Survey Laboratory (KSSL), which is the most comprehensive soil laboratory in the world. In FY 2020, the KSSL conducted analysis and validation on more than 6,100 soil samples collected from individual soil horizons that represent more than 780 soil profiles (pedons). The soil samples analyzed in 2020 come from NRCS and other agency clientele that include soil survey field offices, State soil scientists, resource soil scientists, university cooperators, nongovernmental organizations, plant materials centers, the Natural Resource Inventory (NRI) Soil Monitoring Network, the National Ecological Observatory Network, and outreach activities such as collegiate soil judging. During 2020, the KSSL recorded more than 99,200 analytical results on chemical, physical,

mineralogical, and biological soil properties by more than 50 different analytical methods. This quantitative data is essential for the National Cooperative Soil Survey (NCSS) and NRCS programs such as conservation planning. National programs and research projects depend on KSSL data for soil classification, soil screening and assessment, soil health, and dynamic soil properties.

KSSL is the primary laboratory providing quantitative analyses to support NCSS and NRCS activities around the Nation. In addition, the KSSL develops and maintains standard soil laboratory procedures specifically applicable to soil survey and soil health programs. The latter developed in collaboration with the Soil Health Division (SHD). KSSL also provides technical consultation and reference samples to other soil laboratories, and it participates in lab testing comparisons. In 2020, the KSSL provided leadership in the standardization of analytical methods through participation in the United Nations (UN)-Food and Agriculture Organization (FAO)-Global Soil Laboratory Network (GLOSOLAN). The quantitative soil data produced by the KSSL serves as input for models and interpretations for land use and management, baseline data to assess soil health, and measured values to determine effectiveness of conservation practices and programs (e.g., Conservation Effects Assessment Project, Environmental Policy Integrated Climate model, Revised Universal Soil Loss Equation).

Over the last 9 years, the KSSL has been assembling a mid-infrared (MIR) spectral library, similar to international efforts using soil spectrometry as a low-cost tool for the rapid prediction of soil carbon and other properties. The growing KSSL MIR spectral library represents over 81,000 legacy samples from the KSSL soil archive, the largest public collection in the United States with over 400,000 specimens. Geographically and taxonomically constrained calibration models are being developed for use by NRCS

soil survey field offices for rapid prediction of organic carbon and organic matter, a topic of great interest for soil health and soil resource assessment. For the first pilot project, calibration models were prepared from several thousand Mollisol samples from the Great Plains. Results show low error of prediction for soil organic carbon and soil organic matter. MIR spectrometry allows rapid data collection while assuring data quality and consistency with a tool that any NRCS field soil scientist can use for soil survey and soil health investigations. Based on its demonstrated capacity to produce quality measured data as well its open data policy, the KSSL was nominated by UN-FAO-GLOSOLAN as a world hub for collecting measured and spectral data that would serve global efforts to predict soil properties from MIR spectra. This initiative serves the interests of progressive organized science around emerging technologies that will be useful in the United States and abroad.

NRCS Investments in University Research

The SPSD has invested $3.2 million in 16 collaborative research agreements with 14 universities in 2020 through the Cooperative Ecosystem Studies Units Network (CESU). CESU is a national consortium of Federal agencies, Tribes, academic institutions, State and local governments, nongovernmental conservation organizations, and other partners working together to support informed public-trust resource stewardship. Provisions of the funded research includes student and NRCS scientists' involvement and focuses on key research priority areas. Funded research topics in 2020 included development of soil survey methods for urban areas, informing science-based management decisions for increased soil carbon sequestration and soil health, quantification of blue carbon stocks in tidal freshwaters and coastal marine wetlands, collecting data for saltwater intrusion potential modeling,

developing a dust risk index in the desert southwest, and building soil science capacity through research at University of Texas-Rio Grande Valley, a premier Hispanic-serving institution.

Addressing Priority Pandemic Response Issues: Animal Mortalities Management

In early April 2020, COVID-19 diagnoses among workers at multiple large meat packing plants caused major concern for the livestock industry, particularly for pork producers. Due to the just-in-time nature of modern livestock production, closure of slaughter facilities could easily leave producers with animals that were too large to keep on farm and could not be sold for meat. Producer organizations warned that growers could be faced with no other option but to euthanize large numbers of animals, primarily hogs. These carcasses would need to be disposed of in an environmentally responsible manner. Dairy producers were facing a similar issue with surplus milk that could not be marketed due to closures of major customers including schools. The USDA Animal and Plant Health Inspection Service (APHIS) requested assistance from NRCS to help develop guidance for these livestock producers. The NRCS National Animal Manure and Nutrient Management Team was assigned to coordinate the agency response and requested assistance from agency soil scientists. They quickly identified two existing soil interpretations directly related to livestock carcass disposal which was included in the initial guidelines presented and provided to NRCS staff within a week. Within a few days of this initial response, APHIS asked NRCS for additional assistance to support a new carcass disposal method called shallow burial. This method, which combined aspects of traditional burial and composting, was believed to be more acceptable to farmers since it required less time and did not require special equipment. APHIS also requested information from NRCS to inform disposal of excess milk that was accumulated on farm in

response to market disruptions. NRCS national and regional soil scientists incorporated APHIS-provided criteria for shallow burial into a new soil interpretation based on the format of existing related interpretations. Working collaboratively with the Connecticut State soils staff, they also developed a national milk disposal interpretation based on their existing State-specific prototype. SPSD spatial analysis staff then developed maps and tabular information for both interpretations and made it available to all State soil scientists through an easily accessible web portal. In addition, this new information, along with the types and scope of assistance soil scientists should provide to agency field, area, and State staff was presented on a national webinar accompanied by written guidelines. Fortunately, livestock producers proved to be very innovative and meat packing plants reopened in short order. This prevented the need for widespread carcass disposal. However, these materials will remain available to speed agency response to future emergencies.

Conservation Assessment Ranking Tool

The newly developed Conservation Assessment Ranking Tool (CART) modernizes and streamlines NRCS's conservation planning and program delivery, reduces workload on field staff, and improves the customer experience by creating an efficient application process. The tool combines and analyzes geospatially referenced data and site-specific information provided by the landowner within a decision support system framework. CART will assist NRCS conservation planners to identify the most likely resource concerns associated with the landscape and farm operation and the suite of potentially applicable conservation practices. The tool will provide the landowner with a robust context within which they can identify the most appropriate mix of conservation activities that will meet their

objectives while addressing the relevant natural resource concerns. This informed conversation will lead to wider acceptance of conservation planning recommendations and increased adoption of conservation management practices on the ground. Soils and related data and information are key components of CART. In FY 2020, a team of soil scientists and other technical professionals continued to update and refine the suite of web services that provide real-time soils data to CART v1.0 and CART v2.0 (released in October 2020). In addition, they developed a suite of soil-based interpretations that will help planners and landowner/operators identify the likelihood that resource concerns are present in a selected management area. NRCS staff will use this information to inform field visits, on-farm assessments, and farmer discussions. These focused efforts will lead to more efficient and effective identification of priority resource concerns that can be addressed in collaboration with NRCS. Soil scientists and other technical specialists throughout the Nation continue to collaborate on additions and improvements that will be included in future versions of CART.

10.4. Plant Materials Centers

The NRCS Plant Materials Program includes 25 Plant Materials Centers (PMCs) operated by NRCS to service all 50 States and territories. Each PMC addresses the high-priority conservation concerns within unique ecological areas. When appropriate, PMCs have the ability to coordinate among locations to evaluate vegetative technology and solutions that influence large regions of the United States. This program has been a function within NRCS since the mid-1930s. PMC activities include—

- Developing technology and information for the effective establishment, use, and maintenance

of plants for a wide variety of natural resource conservation uses to improve the establishment of conservation practices and success of farm bill programs.

- Evaluating new plant materials and releasing promising materials to the public for the commercial production of plant materials to protect and conserve natural resources.

- Testing and demonstrating plant materials for specific conservation practices, applications, and purposes to advance agency initiatives/priorities (e.g., soil health, nutrient management, wildlife habitat improvement, and renewable energy systems).

- Providing appropriate training and education to NRCS staff, partners, farmers, ranchers, and the public.

Technology Development and Transfer

The Plant Materials Program develops vegetative solutions to natural resource concerns such as soil stabilization, soil health and productivity, forage production for livestock, water quality, and enhancement of wildlife and pollinator habitat. PMCs provide scientifically sound plant information and tools used by conservation planners and partners.

- Plant Materials Program staff develop technology and methods for both the commercial growers who produce NRCS conservation plants and the landowners, land managers, and

conservationists who utilize NRCS plants in conservation plantings. Technology transfer is a core component of the Plant Materials Program to ensure that NRCS field staff, partners, and other customers have the information they need to establish vegetation for conservation purposes. Plant Materials Program information is integrated into over 30 NRCS conservation practices to support the technical integrity of these practices and provide a direct application to agency conservation activities.

- PMCs continue to increase efforts to tailor plant materials information for specific conservation purposes and to support the agency initiatives. PMCs transferred the results of studies with 41 new study reports, the application of PMC vegetative information in 37 new technical notes or conservation practice implementation requirements, and information on the use, establishment, and management of conservation plants in 19 new or revised plant guides. Seven new regional technical notes on the results of a nationwide study at PMCs to evaluate the adaptation and performance of 58 varieties of commercially available cover crops were completed in 2020. These technical notes, along with other reports from PMCs, are highlighted on a new webpage for cover crop adaptation trials and provide better information for field staff and farmers on appropriate cover crops to use to improve soil health and the resiliency of cropland.

- The Plant Materials Program website consists of over 2,960 technical documents downloaded more than 1.5 million times per year. Plant Materials Program studies resulted in the addition of 183 new technical documents to the website in 2020.

- Plant Materials Program staff conducted 30 technical training sessions for over 1,000 participants in 2020. Training topics included selecting, planting, and managing cover crops; improving soil health; selecting and establishing conservation plants; plant identification; planning a conservation planting; enhancing pollinator habitat; improving the productivity of range and pasture land; planting windbreaks and hedgerows; importance of vegetative covers for preventing erosion; and use of farm equipment. Technical knowledge of the NRCS field staff is improved by holding many of these PMC trainings in conjunction with conservation planner certification training sessions. PMCs provided field days, tours, and presentations to 2,000 participants including NRCS employees, Federal and State Government employees, farmers, ranchers, and the general public. PMC trainings, field days, and tours were significantly impacted in 2020 by COVID-19 restrictions, though many PMCs held virtual events to continue to reach their customers.

- PMC plant materials, plant technology, and management practices are key products used by field staff for the successful implementation of USDA conservation programs such as the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program, and Conservation Reserve Program.

Conservation Plants

PMCs have released 751 conservation plants to the public over their 80-year history. Commercial growers of conservation seeds and plants, many who are in rural communities, grow about 575 of these

NRCS conservation plant releases, and produce enough seeds and plants each year to plant over 2.5 million acres. The seeds and plants have an estimated $100 million annual commercial value. PMC conservation plants support NRCS conservation activities on private lands as well as the National Seed Strategy, a Federal interagency effort to select appropriate plants for restoration and conservation activities.

In 2020, PMCs released six new conservation plants to the public and commercial growers:

- West Bay Germplasm gulf cordgrass (*Spartina spartinae*) was released by the Galliano, Louisiana, PMC. West Bay Germplasm is a native, perennial grass recommended for use in coastal stabilization and restoration projects in coastal marshes and coastal saline prairies of the north central Gulf of Mexico basin.

- Tober Germplasm Virginia wildrye (*Elymus virginicus*) was released by the Bismarck, North Dakota, PMC. Tober Germplasm is a native, cool-season, perennial bunchgrass recommended for conservation cover, pasture and hayland, wildlife habitat, prairie revegetation, riparian plantings, and rangeland seeding throughout North Dakota, South Dakota, and Minnesota.

- Fuego Germplasm Indian blanket (*Gaillardia pulchella*) was released by the Kingsville, Texas, PMC in cooperation with the Texas Natives Seeds program of Texas A&M University-Kingsville. Fuego Germplasm is a native wildflower recommended for pollinator

habitat plantings, upland wildlife plantings, highway right-of-way revegetation, reclamation plantings, and for inclusion in range seeding mixes in the southern and coastal plains of Texas.

- Guadalupe Germplasm white tridens (*Tridens albescens*) was released by the Knox City, Texas, PMC in cooperation with the Texas Natives Seeds program of Texas A&M University-Kingsville and other partners. Guadalupe Germplasm is a warm season perennial grass recommended for critical area revegetation, erosion control, rights-of-way plantings, inclusion in range seed mixes, and wildlife plantings throughout the southern, coastal plain, and central Texas and into west Texas and southern New Mexico.

- Menard Germplasm purple threeawn (*Aristida purpurea*) was released by the Knox City, Texas, PMC in cooperation with the Texas Natives Seeds program of Texas A&M University-Kingsville and other partners. Menard Germplasm is a perennial bunchgrass recommended for upland wildlife plantings, critical site revegetation, right-of-way plantings, and inclusion in range seeding mixes throughout the southern, coastal plain, and central Texas.

- Pineywoods Germplasm thickspike gayfeather (*Liatris pycnostachya*) was released by the Nacogdoches, Texas, PMC. Pineywoods Germplasm is a native, long-lived perennial wildflower recommended for wildlife and pollinator habitat and other native plantings in eastern Texas, northern Louisiana, and southern Arkansas.

10.5. Conservation Practice Standards

The 2018 Farm Bill mandated that all conservation practice standards be reviewed within a year of the signing of the Farm Bill and a report of this activity be sent to Congress. Conservation practices are used to improve natural resources with respect to soil, water, air, plants, animals, and energy, with human considerations a factor in every decision. The NRCS Conservation Practice Standards (CPS) were developed to ensure the conservation practices were installed to specified criteria for protection of the resources, landowner, conservation contractors, soil and water conservation district employees, and NRCS employees.

CPSs evolve in accordance with advancement in farming and ranching techniques used throughout the world and with changes in technology as documented by research, conservation field trials, and accumulated experience. CPSs and other related documents are reviewed periodically (~5 years or sooner as needed). Reviews ensure that standards: (1) provide timely incorporation of new technologies, (2) address or facilitate addressing resource concerns, (3) are consistent in format and content, (4) enhance interagency cooperation, and (5) account for the varied conservation activities expected.

The national discipline lead (NDL) initiates the review or development of a CPS and the associated documentation of NRCS in the future. The standard is reviewed/developed in a multistep process starting with creation of an interdisciplinary review (or development) team (IRDT) to review/develop the CPS. Members of the team must be selected from several geographic areas to ensure that the CPS is compatible across disciplines and is national in scope. The standard is reviewed and updated internally

first, then submitted for public review through the Federal Register before the standard is released. In FY 2020, 58 CPSs were revised.

NRCS updated and revised policy in the NRCS directive Title 450, Part 620, National Handbook of Conservation Practices (NHCP), Subparts A "General Practice Standards Information," and B "Published NHCP Notices," using the newly adopted Conservation Practice Documents-Document Management System (CPD-DMS). The system allows for editing and managing CPS and CPD document processes nationally, and it provides a streamlined process for States to adapt national documents for individual States' use.

10.6. Conservation Engineering

Streamlining and Updating National Engineering Technical Directives

The Conservation Engineering Division (CED) has over 130 National Technical Engineering Directives posted on NRCS's Electronic Directives System (eDirectives). These include the National Engineering Handbook (NEH), Technical Notes (TN), and 49 Technical Releases (TR). Engineering NDLs reviewed the directives and identified that approximately 25 percent of the technical directives were obsolete, and another 60 percent should be incorporated into the NEH and removed from eDirectives. CED is currently updating the NEH and incorporating TNs and TRs. The National Engineering Field Handbook, Part 650 of the NEH, is 90 percent complete and 75 percent of the obsolete directives are in the process of being removed from eDirectives. The removed, obsolete directives will be available on the

engineering technical directives archive webpage.

Collaboration with the American Society of Civil Engineers

NRCS collaborated with the American Society of Civil Engineers' (ASCE's) - NRCS - ASCE myLearning On-Demand Training to offer training for NRCS engineers, geologists, and landscape architects to ensure they have necessary tools and knowledge to perform their jobs effectively and to maintain their professional licensure. NRCS obtained access to 600 individual training webinars and 50 guided online courses. As of October 14, 2020, agency employees completed 408 online webinars, either individually or as a group, and 13 guided online training courses offered through ASCE. This enables NRCS engineering staff to provide our stakeholders with high quality engineering solutions based on current approaches and technology. The current contract runs through the end of FY 2021. NRCS plans to renew the contract for FY 2022.

NRCS National Engineering Handbook

CED continuously updates the National Engineering Handbook (NEH) series to provide NRCS staff and stakeholders with current approaches and technologies for engineering solutions. CED updated the NEH, Part 630, Hydrology, Chapter 5, Streamflow Data, which describes ways to use streamflow data to determine runoff volume from a specific storm event, how to use this information with rainfall data to estimate watershed runoff curve numbers, and how to use the data to determine volume-duration-probability relationships.

National Design, Construction, and Soil Mechanics Center–Soil Mechanics Laboratories

The Soil Mechanics Laboratories consists of two laboratories that perform state-of-the-art soil mechanics testing, geotechnical analyses, and design and construction recommendations adapted to the needs of customers to design and implement conservation practices and systems that conserve, improve, and sustain our natural resources and the environment.

The laboratories provide geotechnical engineering support to all NRCS State and field offices, the Emergency Watershed Protection Program (EWPP), Watershed Rehabilitation Program, Watershed Operations Program, EQIP, wetland restoration, and rehabilitation of aging watershed structures. A few examples include—

- The laboratories performed geotechnical analysis and soil mechanics testing and prepared full reports for the repair and rehabilitation of 18 dams with notable dam safety concerns.

- The laboratories performed geotechnical design analysis, geotechnical testing, and prepared reports for 181 conservation-related engineering structures funded under the mandatory farm bill programs.

- The laboratories updated and compiled all soil and rock testing data into a database used to develop engineering material and varying geologic formation site correlations for research, development of NRCS National CPSs, and geotechnical analysis for individual site

conditions.

- The laboratories provided testing for the development of American Society for Testing and Materials (ASTM) standards which include Crumb Dispersion, Double Hydrometer and Pin Hole Dispersion testing.

- The laboratories developed specialty testing to optimize the amount of lime to mix into soil needed to stabilize earth embankments constructed of high plastic clay soils.

National Design, Construction, and Soil Mechanics Center–Design and Construction

The center provides NRCS with interdisciplinary technical support for design, construction, operation, and rehabilitation of complex engineering projects essential to resource conservation, environmental enhancement, and agricultural productivity. The center provides support to the EWPP, Watershed Rehabilitation Program, Watershed Operations Program, and Environmental Quality Incentives Program (EQIP) and rehabilitation of aging watershed structures. A few examples include—

- Assisted the FBC Employee Development Section (EDS) in providing quality technical instruction for NRCS personnel through formal training courses.

- Performed 55 independent design reviews of high hazard engineering structures and 30 complex conservation engineering practice design reviews for States.

- Provided in class and virtual engineering training for states.

- Assisted States in site-specific engineering issues by performing numerous field reviews, making recommendations, and proposing alternatives in addressing difficult natural resource concerns.

- Represented NRCS on committees responsible for establishing industry engineering standards, such as the ASTM), American Concrete Institute, American Water Works Association, and Association of Agricultural and Biological Engineers.

10.7. National Technology Support Centers

NRCS has three national technology support centers (NTSCs): (1) East NTSC in Greensboro, NC, (2) Central NTSC in Fort Worth, TX, and (3) West NTSC in Portland, OR. NTSCs have two primary functions:

- To collaboratively provide technology transfer, training, and direct assistance to NRCS States and the Pacific Basin and Caribbean Areas, and

- To acquire, develop and support science and technology that efficiently meets the needs of the NRCS conservation delivery system.

As States began implementing a new planning approach utilizing CART, a large number of the NTSC staff also contributed many hours to preparing CART updates for FY 2021. NTSC staff were involved with assisting State technical leads develop suitable technical guidance answer selection in the FY 2020 assessments, developing new national practice narratives, assigning practice points to each narrative for the applicable resource concerns, updating the resource concern assessment portion of CART to incorporate technical updates, and reading and responding to feedback States provided.

The NTSCs are a critical vehicle for technology transfer from NRCS technical specialists down to State and area offices. States submitted over 500 technical assistance requests to the Central NTSC, 482 to the East NTSC, and 637 to the West NTSC to address subjects such as agronomy, engineering, fish and wildlife, manure management, plant materials, soils, water quality, wetland determinations, Monarch butterfly, planning/Field Office Technical Guide (FOTG), economics and social sciences, energy, and CPSs.

NTSCs also provide critical support to the models and tools used by NRCS for conservation planning. A few examples include:

- The NTSCs continue to provide leadership for improvement, testing and training for three web-based applications that make maintaining CPSs and the Field Office Technical Guide more efficient at the national and State levels. Those applications are the CPD-DMS, Conservation Practice Data Entry System (CPDES), and FOTG ver. 5.0. The new design allows integration of both the FOTG and CPDES with the CPD-DMS to improve the user experience and encourages consistency in

document organization. The FOTG revision advances the NRCS mission with improved delivery of high quality science and technology for private lands conservation. NRCS State office staff were provided hands-on training with the new CPD-DMS and CPDES software to manage CPSs. The National Handbook of Conservation Practices was updated to cover changes to the process instituted as a result of CPD-DMS.

- The National Water Quality and Quantity Team (NWQQT), one of the national technology acquisition and development teams, provides assistance to States and NRCS National Headquarters (NHQ) with both water quality and quantity issues. The NWQQT works on both agronomic and engineering solutions and training to address water-related natural resource issues. Activities and technology software include:

    - The successful roll out of the Stewardship Tool for Environmental Performance (STEP) process in CART. The NWQQT has been working on previous iterations of this technology for the last decade. CART utilizes the STEP framework for addressing water quality resource concerns with site-specific conservation planning thresholds that are based on soils and climate. These thresholds can be met with conservation practice credits that vary based on mitigation efficacy for each individual water quality resource concern and contaminant loss pathway. Using STEP in CART helps the NRCS field office delivery system better address water quality concerns in everyday conservation planning. The STEP process was expanded in CART to address additional resource concerns for a more integrated approach to

conservation planning support. For implementation next year variable credits have been developed for multiple practice narratives that focus on specific resource concerns.

- Updated the Pesticide Properties and Toxicity Database to support Conservation Effects Assessment Project pesticide modeling and the Windows Pesticide Screening Tool (WIN-PST) use. WIN-PST is deployed to every NRCS field office and is also available to partners, technical service providers (TSPs), and the public. It is the accepted screening tool for pesticide risk for NRCS conservation planning and program support.

- Substantial progress was made on the development of an edge-of-field (EoF) water quality monitoring reporting and document management system. In FY 2020, the reporting framework was completed and beta testing was initiated. Since 2013, NRCS has funded over 40 EoF projects across the Nation to evaluate the effectiveness of conservation practices in a watershed. These projects yield a large amount of data and the EoF database will provide a system for monitoring partners to efficiently submit data and reports and allow NRCS to efficiently analyze results of the many projects.

- The NWQQT is working with the CarbOn Management Evaluation Tool (COMET) team and Colorado State University to add a water quality component to the suite of COMET products. In FY 2020, alpha testing of the Nutrient Tracking Tool (NTT) in the COMET framework was completed. The project is now moving to beta testing. The COMET Toolbox provides technical support to farmers, ranchers, and private forest landowners who are interested in

evaluating the ecosystem service benefits associated with conservation practice implementation. When an agricultural producer voluntarily implements NRCS conservation practices, those actions can provide quantifiable environmental benefits. These environmental benefits, also known as ecosystem services, provide a value to humanity and may also have an economic value for the agricultural producer. Environmental markets are emerging as a mechanism to compensate agricultural producers for voluntary environmental benefits generated by conservation practice implementation. The COMET tools are designed to help the agricultural producer evaluate the quantity of ecosystem service benefits that are generated through conservation practices. The tools are locality-specific, focus on actual soil and weather data from the agricultural operation being evaluated, and leverage the best available science. The COMET-Farm tool is useful for evaluating carbon sequestration and greenhouse gas emissions, the COMET-Planner tool is used to help farmers and ranchers make conservation planning decisions, and the COMET-Water Quality tool can help evaluate the nutrient and sediment reductions associated with NRCS conservation practice implementation. The COMET tools have demonstrated their utility in supporting voluntary and regulatory environmental markets throughout the country. NRCS's ongoing investments in the COMET Toolbox are fulfilling the needs of the growing interest in environmental markets.

- Worked with the Innovation Center for U.S. Dairy and Field to Market (FTM) on a joint pilot project. This work was part of a cooperative agreement aimed at: (1) leveraging the Innovation Center's FARM ES evaluator network to expand Resource Stewardship

Environmental Evaluation Tool (RSET) adoption and help dairy farmers access RSET in a streamlined fashion, and (2) interpret FTM FieldPrint Calculator inputs into RSET inputs to support data interoperability between the two tools. This project required a high level of agronomy and nutrient management technical expertise and understanding of RSET data inputs. It also required collaboration between different conservation stakeholders, including the Innovation Center, U.S. Dairy, the Maryland/Virginia Dairy Coop, local producers, and local NRCS District Conservationists.

- Supported FTM‘s decision to utilize STEP in their FieldPrint Calculator. This will help facilitate NRCS partnerships with private industry on nutrient and pest management planning that efficiently addresses site-specific natural resource concerns. Private industry supports very detailed nutrient and pest management planning for production purposes. NRCS is interested in tailoring that detailed nutrient and pest management planning to address site limitations that contribute to offsite losses of nutrients and pesticides. FTM using the same risk assessment technology and data as NRCS will allow us to share the large workload of collecting and managing the detailed management data that is needed to support this process for both natural resource conservation and efficient crop production.

- Continues the development and maintenance of nutrient management and pest management technology tools that have been both challenging and rewarding in the closing Conservation Delivery Streamlining Initiative technology development environment and tight funding cycles. As the need for assessing water quality impacts and outcomes in conservation

planning continues to intensify, the need for expertise in the nutrient management arena increases exponentially. NRCS cannot write the number of nutrient and pest management plans that are needed under NRCS Programs activities, so fostering good relationships with USDA partners, conservation districts, land grant universities, TSPs, industry, and nongovernmental conservation partners continues to be critical for continued success.

- Participated in software development/legacy software enhancement with the NRCS Information Technology Center (ITC) in Fort Collins, CO, and Kansas State University on Hydrology & Hydraulic Tools (Animal Waste Management), Engineering Field Handbook, Chapter 2, WinTR-55 Small Watershed Hydrology computer program, and WinPond WinTR-20 Project Formulation Hydrology computer program) with updated rainfall values and newly developed rainfall distributions using the National Oceanic and Atmospheric Administration Atlas 14 data. The NWQQT has also assisted with development of High Level Business Requirements (HLBR) for NRCS Engineering Field Tools (EFT) such as the EFT-Hydrology Tool, EFT- Animal Waste Management, EFT-Farm Pond Design, and EFT-Engineering Data Warehouse.

- The National Animal Manure and Nutrient Management Team (NAMNMT), one of the NTSC national technology acquisition and development teams, provides assistance to States and NRCS NHQ with animal manure- and livestock-related issues. Some of the assistance provided by the team include evaluation of innovative technologies, animal manure- and livestock-related trainings, nutrient management, biosecurity, feed management, and review of animal waste system designs.

- Due to COVID-19 and its impact on livestock and agricultural commodity processing plants, livestock producers had to deal with issues such as emergency milk disposal and animal depopulation. The NAMNMT, along with the NTSC's environmental engineers, developed several guidance documents to help NRCS staff address concerns from producers. These documents included:

    - Emergency Milk Disposal Guidance

    - Emergency Animal Mortality Management Guidance

    - Guidance on Implementation of Shallow Burial as an Emergency Animal Mortality Management Method

    - Feed Management – Changing from a Production to a Maintenance Diet. Even though this material was developed to address the issues related to the pandemic, information provided can be utilized outside of the pandemic.

- The National Air Quality and Atmospheric Change Team (NAQACT) provides assistance to States and NRCS NHQ with issues related to air quality and atmospheric change. In FY 2020, the team collaborated with the USDA Southwest, Southern Plains, Northern Plains, and Midwest Climate Hubs on air quality issues related to their climate work. The group released the USDA Dust Mitigation Handbook, which is intended to be a one-stop resource for dust mitigation on agricultural

lands, rangelands, and natural surfaces. The NAQACT has also continued involvement with USDA ARS and U.S. Environmental Protection Agency (EPA) in the USDA/EPA Agricultural Air Quality Workgroup to discuss agricultural air quality issues of mutual interest. In addition, the NAQACT has spent considerable time in FY 2020 working toward the renewal of the USDA Task Force on Agricultural Air Quality Research (Task Force), which is a Federal advisory committee tasked with providing recommendations to the Secretary on issues related to air quality and agriculture. The Secretary renewed the charter for the Task Force in July 2020, and membership is currently being determined.

- The National Grazing Lands Team provides assistance to States and NRCS NHQ with issues related to all areas of grazing lands management and conservation. In FY 2020, the National Grazing Lands Team:

    - Developed the Determining Indicators of Pastureland Health (DIPH) assessment tool. DIPH includes a matrix of indicators that can be used to determine the preponderance of evidence for three separate pastureland ecosystem attributes: biotic integrity, soil/site stability, and hydrologic function. DIPH is an integral part of the inventory and assessment process in conservation planning. DIPH is used by our field staff and ranchers to assess how well ecological processes such as water cycle, energy flow, and nutrient cycling are functioning at a site.

- Revised 5 chapters of the NRCS National Range and Pasture Handbook; the remaining 6 chapters will be completed in 2021. The National Range and Pasture Handbook provides procedures in support of NRCS policy for the inventory, analysis, treatment, and management of grazing land resources.

- Developed 3 new courses for the National Grazing Lands Curriculum: Vegetation Monitoring and Data Assessment, Grazing Land Economics, and Prescribed Grazing. Team members serve as subject matter expert, instructor or technical coordinator for the other curriculum courses: Range Ecology I, Range Ecology II, Rangeland Ecohydrology and Interpreting Indicators of Rangeland Health. The National Grazing Lands Curriculum offers courses in grazing land management for NRCS employees at NRCS State and field offices.

- Provided Rangeland Hydrology Erosion Model updates to the ARS Great Basin Rangelands Research Unit in Reno, Nevada.

- Provided technical assistance to U.S. Forest Service Bridger-Teton National Forest, Erosion Risk Analysis: Data analysis and report.

- Analyzed NRI data regarding milkweed and monarch butterfly and submitted paper to Ecosphere.

- NRCS's suite of erosion prediction tools maintenance and development includes use of the

Integrated Erosion Tool (a new version 2 (IET2) is currently in testing), Wind Erosion Prediction System, the Revised Universal Soil Loss Equation, and developing Water Erosion Prediction Project for NRCS use. Evaluation of these tools in cooperation with USDA ARS continues to improve the efficiency and effectiveness of field-level predictions of wind and water erosion during the conservation planning process.

10.8. Science and Technology Training Library

NRCS's NTSCs and Soil Health Division (SHD) work with partners including the U.S. Forest Service, land-grant universities, and the extension service to make available to conservation planners and natural resource managers up-to-date training webinars on diverse topics, including forestry, climate change, bioenergy, wildlife, soil health, conservation planning, and organic agriculture. The Science and Technology Training Library can be found at: http://conservationwebinars.net. Some of the webinars are developed by NRCS staff, others by partners. These webinars may be viewed live or on-demand. In FY 2020, these webinars in the Training Library were viewed by over 9,844 individuals, including both NRCS and non-NRCS participants. More than 2,176 continuing education units (CEUs) were issued to maintain professional certifications for NRCS employees, partners, and other participants. The decrease in the numbers of individuals viewing these webinars and the number of CEUs issued for FY 2020 from FY 2019 results from the webinar portal agreement not being signed until the second half of the fiscal year.

10.9. Soil Health

Adoption of soil health practices, especially soil health management systems, provides benefits for agricultural resilience to weather and pest challenges, risk, production economics, yields, crop quality, nutrient cycling, water quality and quantity, and climate change adaptation and mitigation. Soil health is foundational to the agency's work. NRCS launched its Soil Health Initiative in 2012 to refocus agency efforts on improving the physical, chemical, and biological functioning of soil on private lands and, shortly after that, established the national SHD. The SHD provides leadership on strategy, policy, training, direct assistance, science and technology integration, programs integration, and leadership to soil health efforts within the agency, with partners, and customers across the country. NRCS's soil health activities have expanded significantly at State and national levels, and interest in soil health has spread rapidly to partners and stakeholder groups, including the corporate agricultural sector and large landowners making decisions on millions of acres of land. The NRCS Conservation Practice Standard Cover Crop (Code 340) ranks among the top soil health EQIP cost-shared practices in FY 2020.

In an address to the agency in February of 2020, Chief Lohr challenged each State to develop a soil health strategy to achieve soil health integration across the agency and field staff becoming the customers' greatest trusted source of soil health information. The SHD developed a national State strategy template for State use in this process, which compiled successful strategies and approaches from States across the Nation who have built successful soil health efforts over the past years. The SHD then significantly assisted 23 States on soil health strategy development. All States now have and are implementing a soil health strategy. State soil health leadership who are responsible for soil health

attended four quarterly meetings hosted by the SHD to coordinate soil health efforts across the nation. The SHD additionally documented every State's priorities for national soil health assistance and leadership directly with State conservationists.

Since SHD's inception in late 2014, the division performed soil health-related outreach and technology transfer reaching hundreds of thousands of people through presentations, workshops, technical assistance, staff and partner trainings, and demonstrations. Thousands of additional participants attend State-led soil health events annually. In FY 2020, SHD staff provided training on a wide range of soil health assessment and management topics at more than 200 events, including soil health trainings, presentations and demonstrations to agency staff or mixed stakeholder and grower audiences. SHD reached thousands of NRCS and Soil and Water Conservation District employees as well as producers nationwide. The SHD conducted 20 soil health certification courses to approximately 400 agency employees and partners. An additional 52 trainings were canceled because of the pandemic. To remedy the impact of reduced in-person staff trainings for conservation planner certification resulting from the pandemic, SHD modified all PowerPoint presentations for a virtual or live streaming delivery, developed on-demand videos of each of the nine modules for the soil health certification course, and made a virtual version of the course available to States in AgLearn.

To further expand the virtual reach of national conversation and training on soil health across the NRCS stakeholder and customer base, the SHD also started the monthly Conversations on Soil Health Broadcast series. Six events were held in FY 2020, each attended by 300–500 participants, with 5,203 total views by staff in Microsoft Teams and greater than 1,300 additional views by staff and customers

on the agency YouTube channel. These conversations complement 83 soil health-related webinars that are available to the public on demand at the NRCS Science and Technology Training Library. These webinars attracted nearly 3,000 attendees in FY 2020. NRCS's Science of Soil Health videos, available on YouTube, have been viewed over 592,000 times.

Several national bulletins, technical notes, and other technical materials were developed including:

- Soil Health Specialist's Toolbox 2.0 provides an overview of effective soil health demonstration materials that staff and partners can use in their work with customers.

- Soil Health Resource Concerns implemented in policy (National Bulletin (NB) 450-20-1), including updates to the compaction and organic matter depletion resource concerns that were previously available, as well as two new resource concerns: soil organism habitat degradation and aggregate instability.

- National template for In Field Soil Health Assessment (NB 450-20-2) made available to allow field staff to identify and document soil health resource concerns, and the use of the assessment was integrated into the new CART.

- Technical Note 450-04, "The Basics of Addressing Resource Concerns with Conservation Practices within Integrated Soil Health Management Systems on Cropland."

- Technical Note 450-05, "Full-Scale Rainfall Simulator Instructor Guide." This technical note was developed to provide NRCS instructors, conservation planners, and partners a comprehensive guide to performing the full-scale rainfall simulator and slake test demonstrations.

- Conservation Activity Plan 116, Soil Health Management Plan, available to meet Farm Bill 2018 mandate for providing technical and financial assistance for soil health management planning.

- Conservation Activity 216, Soil Testing, available to meet Farm Bill 2018 mandate for providing technical and financial assistance for soil health testing.

- Interim Conservation Practice Standard Soil Carbon Amendment (Code 808), developed with involvement of State staff across the agency, rolled out, and modified with further input for FY 2021 use.

- Eight soil health economic case studies codeveloped and cobranded with American Farmland Trust through a conservation innovation grant.

- Series of 25 "How To" soil health videos codeveloped with University of South Carolina through an agency agreement providing strategies to producers in the semiarid West in overcoming significant regional challenges in their soil health management system

implementation. These videos are being released in quarter 1 of FY 2021.

The four Cover Crop Councils (Midwest, Northeast, South, and West) provide structure for compiling the practical science from across the cover-cropping community and transferring it to farmers, ranchers, and other landowners across organizational boundaries. The Northeast Cover Crop Council developed their species selection tool for adoption by the other three Cover Crop Councils. This tool is a template of a national tool for cover crop management decisions that will be housed at the National Agricultural Library through collaboration between NRCS, ARS, land-grant universities, and the Cover Crop Councils and their members.

The second cohort of Conservation Innovation Grants (CIG) Soil Health Demonstration Trials has been selected based on agency technical priorities related to soil health implementation. This subset of CIGs will produce a national outcomes dataset, including soil health status, management, and economic, environmental and social outcomes. Fifteen of these Soil Health Demonstration Trial projects were funded in FY 2020. These cooperative grants to organizations leading the trials in nearly 40 States and U.S. territories total to nearly $25,000,000. The trials will develop a better understanding of and guidance for key implementation gaps, including, but not limited to cover crop species and variety selection for specific purposes/regions, evaluating cover crop termination techniques, interseeding cover crops, developing cover crop recommendations for water-limited operations, developing online colearning environments to promote technology transfer and idea sharing among producers; tracking soil, economic and social changes resulting from Soil Health Management System adoption, developing Soil Health Management Systems for perennial crops, and incorporating management-intensive

rotational grazing in various systems.

Highlight Story: Making Fundamental Changes to a Ranching Operation in Weston, Wyoming

Figure 1. Jake Boller and Tim Kellogg discussing soil health principles.

Photo: Marlon Winger

Producer Jake Boller's old alfalfa and grass hay fields had not been productive and required him to purchase additional hay for his cattle, adding expense to his operation. So, Jake met with District Conservationist Tim Kellogg and Regional Soil Health Specialist Marlon Winger from SHD to help him make fundamental changes in how he managed his cow-calf operation. Jake implemented all of the principles of soil health, sold his hay equipment, and purchased a no-till drill and a herbicide sprayer mounted on a pickup truck. Jake chemically terminated the existing forage stand and drilled a 10-species

cover crop mix that included a variety of cool and warm season grasses, legumes, and forbs. Equipped with his new no-till drill, Marlon and Tim taught Jake how to build a cover crop mix that would address the inadequate forage supply in his fields that resulted from a lack of diversity and poor soil function. Jake fundamentally changed how he harvests forage by letting the cattle graze 250 acres of cover crops with virtually no harvest costs (swath, rake, bale, haul off the field and then feedback on a field). Forage yield was clipped, weighed, and estimated at 10,000 plus pounds per acres, compared to his average of 3,000 lbs of hay harvested per year. Jake is in the second year of an NRCS EQIP contract and he is very happy with the outcome so far. He told Tim that previous year's total cow expenses were about $550 per cow; however, by incorporating soil health principles, his reported cost is now about $150 per cow. In the West winter-feeding costs are the dominant expense for a rancher, and 2020 was a dry year. So, Jake learned the valuable lesson of keeping the soil covered, allowing precious moisture to be conserved for plant growth and ultimately greater profit for the ranch.

10.10. Watershed Protection and Dam Safety

EWPP helps local communities relieve imminent hazards to life and property caused by floods, fires, windstorms, and other natural occurrences that cause watershed impairments. EWPP has two distinct options for assisting landowners in affected areas: EWP-Recovery and EWPP-Floodplain Easements. The EWPP Tool is a software application designed to help NRCS staff create and manage EWP projects more efficiently. The EWPP Tool follows the EWP process from the designation of a State disaster and submission of the electronic disaster report (EDR), through the damage survey report (DSR) preparation and submittal, to project and funding approval. In FY 2020, the EWPP Tool was used to submit 100

percent of the EDRs and DSRs, thereby allowing project tracking and documentation of funding decisions.

NRCS DamWatch®.—DamWatch is a web-based application developed for the USDA NRCS by USEngineering Solutions Corporation (USES) to assist watershed project sponsors to monitor and manage 11,800 NRCS-assisted dams. This tool provides real-time monitoring of rainfall, snowmelt, stream flow, and seismic events that could pose potential threats to dam safety. DamWatch also forecasts rainfall events to allow NRCS personnel and project sponsors to prepare for potential events at the dams. DamWatch alerts essential personnel through email, fax, or text message when dams experience one or more of the potentially hazardous monitored conditions. This allows for the coordinated deployment of personnel and resources at the right time and place. DamWatch provides a "one-stop" source for accessing critical documents, databases, onsite electronic monitoring devices, and geospatial information through a secure interactive web interface. This allows NRCS and watershed project sponsors to manage a proactive response. Important project dam information includes as-built plans, operation and maintenance agreements, emergency action plans, inspection reports, photos, videos, and assessment reports. DamWatch offers project sponsors an effective means for managing watershed projects. Although NRCS personnel may elect to receive DamWatch alerts, the project sponsor maintains responsibility for monitoring the dams and notifying authorities during an emergency.

10.11. Snow Survey and Water Supply Forecasting

The National Water and Climate Center (NWCC) and Snow Survey and Water Supply Forecasting

Program (SSWSF) collaborate on hydrologic forecasting advancements with universities and researchers. NWCC also supports the Soil Climate Analysis Network (SCAN) further contributing data to the Water and Climate Information System. NWCC is advancing infrastructure to support forecast modeling using the Multi-Model Machine Learning Metasystem (M4) through a Cooperative Ecosystem Studies Unit (CESU) agreement with Colorado State University. Another CESU agreement with Portland State University supports parameter inputs and hydrologic basin analyses. NWCC has a cooperative agreement with the USDA ARS in Boise, Idaho, to enhance physically based distributed snowmelt modeling. These contracts improve the SSWSF's ability to forecast water supplies. Finally, the NWCC's interactive map is a useful tool providing a more intuitive interaction with water- and climate-related data. Allowing presentation of data from multiple agencies the map interface is a form of collaboration reducing need to navigate various locations and provides in-depth user-friendly analysis.

10.12. The National Resources Inventory

The National Resources Inventory (NRI) has an ongoing agreement with Iowa State University (ISU) to improve ways of providing information on the status and trends of national land use characteristics and soil erosion. ISU is conducting research on model-assisted county-level and other sub-State estimates to further the application of NRI data in environmental analyses, as well as the use of machine learning and artificial intelligence to speed up the monitoring of land use change. NRI personnel are also in the process of updating the handheld portable devices that are used to collect environmental information in the field. The new system will insure the accurate collection of field data and submission to NRI data servers through the internet.

10.13. Conservation Innovation Grants (CIG)

Another important vehicle for development of conservation technology that NRCS will then transfer to farmers and ranchers is CIGs. A component of NRCS's EQIP, CIG is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging Federal investment in environmental enhancement and protection in conjunction with agricultural production. Under CIG, EQIP funds are used to award competitive grants to non-Federal governmental or nongovernmental organizations, Tribes, or individuals.

CIG enables NRCS to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the Nation's most pressing natural resource concerns. CIG benefits agricultural producers by providing more options for environmental enhancement and compliance with Federal, State, and local regulations. NRCS administers CIG. Much of what NRCS learns from CIG is incorporated into conservation practice standards used by the field conservationists and technicians to address resource concerns on private farms and ranches.

Since CIG's inception in 2004, NRCS has awarded over 700 national-level CIG grants. In FY 2020, 38 national-level CIG grants were awarded. There is also a State-level component that NRCS State offices may use to award smaller grants for State-specific resource concerns. Lists and brief summaries of funded projects are available on the CIG website: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig.

11.0. Rural Development (RD)

11.1. Mission Statement

USDA Rural Development (RD) is committed to helping improve the economy and quality of life in rural America. RD provides loan and grant financing as well as technical assistance to develop housing, community facilities, businesses, infrastructure, and renewable energy ventures in rural areas. In addition to providing direct loan and grant assistance, USDA Rural Development also partners with private sector lenders and development organizations to carry out local community development projects. Rural Development's more than 40 financial assistance programs, in addition to its ability to leverage private sector resources, give USDA the flexibility to invest in a wide range of projects that are reinvigorating rural towns and building strong and economically robust communities.

With a total portfolio of more than $220 billion and investments upwards of $30 billion in 2020 alone, Rural Development is making lasting investments in rural communities. The mission area has a tremendous set of business, utilities, housing and community development programs designed to ensure that rural Americans have access to safe, affordable homes and community facilities, jobs and business capital, and the benefits of drinking water, broadband, electricity and other essential services.

11.2. Nature and Structure of Program

RD is a program-oriented organization that provides a vast array of grant, loan, loan guarantee and technical assistance programs to rural Americans. RD financial programs support such essential public facilities, services and infrastructure as water and sewer systems, housing, health clinics, emergency service facilities and electric, broadband and telephone service. We promote economic development by supporting loans to businesses through banks and community-managed lending pools. We offer technical assistance and information to help agricultural and other cooperatives get started and improve the effectiveness of their member services. And we provide technical assistance to help communities undertake community empowerment programs.

Rural Development achieves its mission by helping rural individuals, communities and businesses obtain the financial and technical assistance needed to address their diverse and unique needs. Rural Development works to make sure that rural citizens can participate fully in the global economy and plays a lead role in improving the economic climate of rural areas through creating and preserving business opportunities and jobs. Through our partnerships with other public and private sector businesses, our programs help close the opportunity gaps between under-served rural and productive metropolitan areas.

Although RD does not have a formal technology transfer program in place, the agency does oversee the Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (Section 9003), which assists in the development, construction, and retrofitting of new and emerging technologies

for the development of advanced biofuels, renewable chemicals, and biobased product manufacturing by providing loan guarantees for up to $250 million.

The purpose of the program is to assist in the development of new and emerging technologies for the development of advanced biofuels, renewable chemicals, and biobased product manufacturing. This is achieved through guarantees for loans made to fund the development, construction, and retrofitting of commercial scale biorefineries using eligible technology and of biobased product manufacturing facilities that use technologically new commercial scale processing and manufacturing equipment and required facilities to convert renewable chemicals and other biobased outputs of biorefineries into end-user products on a commercial scale. RD's Rural Business-Cooperative Service has the responsibility for administering the program.

RD's rural energy programs help increase American energy independence by increasing the private sector supply of renewable energy and decreasing the demand for energy through energy efficiency improvements. Over time, these investments can also help lower the cost of energy costs for small businesses and agricultural producers.

RD also oversees the Alternative Technology Transfer for Rural Areas (ATTRA) project carried out by the National Center for Appropriate Technology (NCAT). The ATTRA project works to provide information to farmers and other rural users on a variety of sustainable agricultural practices that include both cropping and livestock operations. Additionally, ATTRA encourages agricultural producers to

adopt sustainable agricultural practices which allow them to maintain or improve profits, produce high quality food and reduce adverse impacts to the environment.

Work for the ATTRA project takes place at all seven NCAT office locations. The ATTRA project is staffed by more than 20 NCAT agricultural specialists with diverse backgrounds in livestock, horticulture, soils, organic farming, integrated pest management, and other sustainable agriculture specialties. The ATTRA project supports a nationally recognized, virtual resource center (www.attra.org) that is accessible by farmers, ranchers, market gardeners, Extension agents, researchers, educators, farm organizations, and others involved in agriculture, especially those who are economically disadvantaged or belong to traditionally underserved communities. ATTRA provides technical assistance through publications and/or customized resource packets.

ATTRA receives funding through the annual appropriations bill which directs Rural Development to administer the funding through a cooperative agreement. The annual funding for ATTRA is administered by Rural Business-Cooperative Service.

The 2018 Farm Bill transfer the Biobased Markets Program (a.k.a. Bioprefered) to Rural Development. The program's purpose is to spur economic development, create new jobs and provide new markets for farm commodities. The increased development, purchase, and use of biobased products reduces our nation's reliance on petroleum, increases the use of renewable agricultural resources, and contributes to reducing adverse environmental and health impacts. While the BioPreferred Program does not provide

financial support for its participants, USDA's Rural Development agency offers loan and grant programs that may be applicable.

11.3. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)

While RD did not have any specific goals related to technology transfer, RD programs support entrepreneurs and rural businesses implement technology through an array of loan, loan guarantee, grant and technical assistance programs. RD works to support technology transfer by creating linkages and supporting partnerships and collaborations with other Federal agencies, universities, and other organizations that can improve access and deployment of proven technology in rural areas. For example, through various programs, RD investments are support connecting rural communities to the future through broadband and e-connectivity projects. Other examples include, advanced manufacturing, business incubators, business accelerators, renewable energy systems and energy efficiency improvements. Examples of how producers and small businesses are using RD programs to implement technology advances include: distance learning and telemedicine, lighting, refrigeration, high efficiency heating, ventilation and air conditioning systems, cooling or refrigeration units, electric, solar or gravity pumps for sprinkler pivots, and replacement of energy-inefficient equipment. Additionally, RD funds are being used to support new technology in the processing and marketing of value-added food products that are contributing to the development of a more robust local and regional food system.

11.4. Strengthening Current Activities

Through a diverse portfolio of programs and network of State offices, RD achieves its mission by helping rural individuals, communities and businesses obtain the financial and technical assistance needed to address their diverse and unique needs. Rural Development works to make sure that rural citizens can participate fully in the global economy and plays a lead role in improving the economic climate of rural areas through creating and preserving business opportunities and jobs. Through our partnerships with other public and private sector businesses, our programs help close the opportunity gaps between under-served rural and productive metropolitan areas.

RD foresees the Biopreferred program as an opportunity to highlight the use of alternative technologies and expand consumer awareness to support the bioeconomy. Biobased products are derived from plants and other renewable agricultural, marine, and forestry materials and provide an alternative to conventional petroleum derived products. Biobased products include diverse categories such as lubricants, cleaning products, inks, fertilizers, and bioplastics. For the purposes of the BioPreferred Program, biobased products do not include food, animal feed, or fuel. Many of the products included in the Biopreferred program are the result of the incorporation and commercialization of new and innovative technologies.

RD continues to enhance its Web presence to make information and programs more accessible to the public as well as concentrate outreach efforts to ensure that businesses and communities in greatest need have access to the necessary resources to be competitive.