USDA ANNUAL REPORT ON TECHNOLOGY TRANSFER

FY-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. PCT = Patent Cooperation Treaty.

	FY 2017	FY 2018	FY 2019		FY 2020	FY 2021
Invention Disclosures						
New inventions disclosed	193	320	243		213	187
Patents						
Patent applications filed	125	115	97		91	93
Patents issued	74	67	71		58	45
Foreign Patenting						
Foreign patent applications filed	ND	ND	ND		61	16
PCT applications filed	ND	ND	ND		16	19
Foreign patents issued	ND	ND	ND		5	7

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 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total Active Licenses	438	473	512	582	624
New Licenses	38	41	51	93	51
Total Income, All Active Licenses	$5,703,000	$3,835,000	$3,562,000	$3,244,000	$3,132,189
Total Income, Invention Licenses	$5,378,000	$3,495,000	$3,275,000	$2,969,000	$2,890,924
Total Earned Royalty Income (ERI)[1]	$3,503,891	$2,716,369	$3,171,495	$2,678,183	$2,399,480
Median ERI	$3,698	$3,056	$3,154	$4,221	$3,738
Minimum ERI	$15	$21	$ 0.75	$13	$0.02
Maximum ERI	$769,167	$265,844	$573,545	$279,915	$310,589
ERI from top 1% of licenses	NP	NP	NP	NP	NP
ERI from top 5% of licenses	$1,639,557	$1,218,975	$1,579,185	$1,111,917	$1,068,082
ERI from top 20% of licenses	$2,933,342	$2,227,058	$2,655,368	$2,210,427	$2,107,125
ERI distributed[1]					
Percentage distributed to inventors	25	25	25	25	25

Percentage distributed to lab/agency	0	0	0	0	0
Innovation Fund[2]	$483,814	$618,000	$833,500	$898,144	$556,135
Licenses terminated for cause	0	0	0	0	0

[1]Only reported for ARS.
[2]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.

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
CRADAs					
Active CRADAs	329	218	260	221	377
Newly executed CRADAs	91	61	95	84	79
Active CRADAS with small businesses[1]	62	73	120	64	24
New CRADAs with small businesses[1]	17	32	41	21	15
MTRAs[2]					
Active MTRAs	443	369	305	336	333
Newly executed MTRAs	112	133	113	119	97
Other Collaborative Research Agreement[3]					
Active other collaborative research agreements[2]	4,108	3,215	1,888	1,987	2,443
New other collaborative research agreements	1,061[1]	775[1]	1,122[1]	4,167	3,480

[1]Only reported for ARS and APHIS.
[2] Only reported for ARS— combines Technology Transfer and Trust Fund Cooperative Agreement Authorities.
[3] Trust Fund Cooperative Agreements, Reimbursable Agreements, Specific Cooperative Agreements and Non-Funded Cooperative Agreements, Cooperative Agreements, Inter-agency and 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 the innovative technologies and the "internet of things" have been used to assist agency stakeholders in marketing their food and fiber commodities. AMS programs and services include: Market News Service, Shell Egg Surveillance and Standardization, Market Protection and Promotion Programs, Transportation and Marketing, Packers and Stockyards Programs, Federal Grain Inspection, U.S. Warehouse Activities—Warehouse Commodity Management, International Food Procurement,

Payments to States and Possessions, Commodity Research and Promotion Programs, Commodity Grading, Verification and Plant Variety Program, Perishable Agricultural Commodities Act Program and Strengthening Agricultural Markets and Producer Income. 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 and the internet of things.

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 2021, FDLD continued its outreaching activities to help regulated entities understand the requirements of the NBFDS, and FDLD staff continued with outreach and informational presentations at conferences, reaching over 1500 people. FDLD also responded to 853 questions received via the newly created BE inbox. FDLD completed 58 supplier traceback audits, 3,343 initial retail reviews, 270 follow-up retail reviews, and responded to 14 consumer complaints. In FY 2021, FDLD did not

complete any supplier traceback audits due to the new customer relationship management (CRM system); however, FDLD did complete 2,304 initial reviews, 116 follow-up retail reviews, and responded to 6 consumer complaints.

In FY 2021, FDLD initiated its transition to a customer relationship CRM system that will automate a number of tasks 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 enabling leadership to make strategic decisions and track progress toward objectives in their annual operating plans.

1.4. National Organic Program (NOP)

USDA oversees organic agricultural products through the Agricultural Marketing Service (AMS), National Organic Program (NOP). NOP develops the national standards for organically produced agricultural products sold in the United States. The program accredits and provides oversight of third-party organizations, called certifiers, who certify organic farms and businesses to the USDA organic regulations. USDA and accredited certifiers also enforce the organic standards, protecting farmer and consumer confidence in the integrity of the USDA organic seal.

The number of certified organic farms and businesses continues to steadily grow. Rapid growth across the global organic market has increased the complexity of supply chains that carry organic products

from farm to table. To oversee this complex and growing market, NOP leverages a wide range of technology products.

1.4.1. Organic Integrity Database

The Organic Integrity Database has significantly increased the transparency and availability of data for those involved in organic trade, increased the visibility of organic businesses, and directly advances NOP compliance and enforcement work. The Federal organic regulations currently require certifiers to annually submit a set of basic facts regarding all certified operations to the database. The database lists certified products for each farm and business, providing a resource for other companies looking for certified organic ingredients or needing to bolster their supplies. It also includes many optional fields, like acreage, that can aid in oversight and enforcement.

1.4.2. Compliance Database

AMS launched an internal Compliance Database in spring 2019 and has continued its improvement to date. The database captures complaint data submitted through the online complaint portal, helps to better track NOP's progress on complaint investigations, and more quickly identifies patterns and relationships across complaints.

1.4.3. ACCREDIT Database

NOP accredits and oversees about 75 certifiers. Certifiers play a critical role in maintaining the integrity of USDA certified organic products worldwide. As part of its risk-based certifier oversight, NOP

manages the certifier accreditation lifecycle, audit communications and non-compliances through its ACCREDIT Database. In 2020, NOP launched improved system capabilities, expanding farm to market traceability, and facilitating increased supply chain integrity.

1.4.4. Organic Integrity Learning Center

The Organic Integrity Learning Center, launched in April 2019, provides free, on-demand, online training to support the professional development and continuing education of certifier staff, inspectors, and compliance specialists working to protect organic integrity. As of October 2021, more than 5,850 people have signed up and taken 1 or more of the 22 full-length courses and 8 microlearning courses available. Topics range from basic certification to advanced enforcement techniques. Examples of courses added in 2020–2021 include: Organic System Plans, Certification Review, Traceability Techniques, Input Material Review, Preventing the Organic Fraud Opportunity, Yield Analysis, Evaluating Corrective Actions and Sampling and Testing.

1.4.5. U.S. Customs and Border Protection's Automated Commercial Environment (ACE)

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 U.S. Customs and Border Protection (CBP) to 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.

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 will 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 will allow Government oversight bodies to audit across supply chains, fulfilling the goal of tracing products from farm to market and back. The system will 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 as this market sector continues to grow worldwide.

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) and the public facing "My Market News" component. MARS allows AMS to manage and publish Market News data in one centralized customer facing database, replacing multiple legacy systems. This 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 2021, MARS and its public facing website, My Market News (MMN), continued to add more market types and reports to those available to the public. Through My Market News, users can access over 700 unique market reports disseminated from over 45 Market News offices across the country. Users can access all data and reports for the market types of Dairy Point of Sale, Dairy Cold Storage, Cotton Quality, Cotton Forward Contract, Cotton Organic, Cotton Yearly Varieties, Tobacco Stocks, Specialty Crops Trends, Specialty Crops Truck Rates, Livestock & Poultry (L&P) Egg Inventory, L&P Cold Storage, L&P Live Auction, L&P Video Auction, L&P Direct Livestock, L&P Grain Pricing, L&P Hay Auction, L&P Direct Hay and L&P Rice Pricing.

Development work has been completed on the following Market Types and these are all are nearing the final stages of completion in preparation for full deployment to MARS production. These include Retail for all Programs, Specialty Crops Movement, Specialty Crops Terminal, Specialty Crops Shipping Point, L&P Feedstuffs Pricing, L&P International reports, and L&P National Feeder Cattle Summary. Development work was also completed on a major redesign of the MMN website and the MARS AP) that will accommodate the structure to release Specialty Crops data to AMS customers and align it with current processes. 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 API, customers can now access data from over 685 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 2022, reducing costs to annual system support and maintenance.

Technology Accomplishments for AMS Market News include:

- Completion of all of the MARS work for the market types of Truck Rates and Trends to be
  completely transitioned to MARS and have all published data from these reports available on
  MMN and in the API;

- Completion of the development work for Terminals, Shipping Point, Movement and Retail;

- Conducting testing on many different market types and new features in MARS, along with the
  new Specialty Crops interface in MMN;

- Completing the process of documenting requirements for remaining work in MARS that is
  needed to complete the transition of all Specialty Crops market types from the legacy system into
  MARS and MMN;

- Finished testing of a new Cornell Mann Library upgraded site and file repository;

- Determining issues with the My Market News user interface and proposal of changes needed;

- Upgraded to VM Servers for sunsetting MNIS and MNCS;

- Revised header statement for all Free on Board (FOB) reports; and provided several reporters
  with access to the U.S. Customs Automated Commercial Environment (ACE) system with plans

to transition northern U.S. border reporting of import and export data sources from Cognos to the

ACE International Trade Data System (ITDS).

Additionally, AMS Market News developed the first ever USDA Market News mobile application

which will be available for free from both the Apple and Google Play stores in early FY2022. The

USDA Market News mobile application provides instant access to market reports and information

published by the U.S. Department of Agriculture. This information gives farmers, producers, and

agricultural businesses the information they need to evaluate market conditions, identify trends, make

purchasing decisions, monitor price patterns, evaluate transportation equipment needs, and accurately

assess commodity movement. The USDA Market News mobile application allows users to search and

view market reports, identify reports by user location, subscribe to reports, add reports to favorites for

easier access, and share reports and data with colleagues.

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. In FY2021, NSL operated without any stoppages throughout the

entire pandemic, having actively monitored and mitigated impacts to minimize the effect on customers,

including supply chain issues. NSL implemented new data analytics strategies using Tableau interactive data visualization software with scripting in the Python programming language to better monitor and manage laboratory operations including finances, staffing, and sample load. This new strategy was critical for understanding the full impact of the pandemic and led to cross-utilization of staff in areas with the highest sample load.

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 2021, NSL worked to implement a new technology for testing honey for adulteration and also for testing hemp for cannabinoid content. Additionally, a new technology that was implemented in FY 2020 for microbiological testing was expanded to analyze for additional organisms in FY 2021. In FY 2021, NSL implemented the LIMS inventory module for all supplies and consumables, streamlining inventory accounting and creating efficiencies with the quality management system and purchasing.

NSL 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 2021, due to the COVID-19 pandemic restrictions, to carry out its mission, LAS continued to provide audit services, conducting 84 percent of its audits, remotely in a virtual environment. In FY 2021, LAS prepared for implementation of its new mobile auditing and client management application, Extensible Assessment Manager (ExAM) by configuring it for use with each of the four laboratory approval programs (LAP) it administers and updated the primary quality assurance and procedural documents to align with ExAM. In FY 2021 LAS improved the LAP application process by developing a workflow with clear delineations of the process phases, roles and responsibilities, record management requirements, decision points, and communications required. LAS successfully implemented the process resulting in decreased time to grant approval and improved customer experience. In FY 2021, LAS led collaboration of the U.S. peanut industry and competent authorities (AMS, FAS) to resolve a long standing issue that hampers peanut export and developed an action plan to expand the scope of the Laboratory Approval Program for Analysis of Aflatoxin (LAP-Aflatoxin) to meet the European Union's (EU) testing requirements. LAS provided strategic guidance and expertise to the U.S. pistachio industry and competent authorities (FAS, SCP, FDA) on EU's proposed regulation of ochratoxin A in pistachios and are prepared to further expand the scope of the program to maintain the pistachio industry's ability to trade with the EU.

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 2021, 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 reproduced, tuber-propagated, or asexually reproduced. This voluntary program is funded through application fees for certificates of protection. Currently, more than 200 species of plants are protected under the PVP Act and more than 8,340 certificates of protection are in force. In FY 2021, the Plant Variety Protection Office (PVPO) received 500 applications of new seed, vegetative, and tuber propagated agricultural and ornamental plant varieties, conducted examinations on 450 applications to determine if plants were a new variety, and issued 425 certificates of protection. PVPO also implemented the sixth release to update its electronic application system to allow for the bulk upload of corn and soybean applications, add the ability for customers to attach supporting documents in the system, provide new report and search features to the portal, and add advanced variety distinctness search capabilities to the internal 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 that 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. These partnerships stabilize and support the robust $12 billion U.S. seed market.

Recent activities conducted by SRTD to facilitate domestic and international marketing include the development of a new test method to verify the Kentucky 31 variety of tall fescue. Kentucky 31 is a popular variety of grass seed that is often contaminated by other similar grass seed species. The only method to distinguish between these species are through field grow-outs which can take up to 9 months to complete. Due to this long timeframe which extends beyond most planting seasons, buyers and sellers often draw contracts for this variety not knowing if the lot has been contaminated. The new test method will reduce testing time to approximately 6 to 8 weeks, allowing sellers time to appropriately price and label seed lots.

In FY 2021, SRTD began development of a new case storage database 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 thousands of dollars in contracting fees. SRTD will begin beta testing in the first quarter of 2022. The new system will allow division specialists to

conduct the same searches and record storage functions as the legacy system. The new system will also allow 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 systems 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 Packers and Stockyards 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.

Over the last few years, WCMD has modernized its information technology infrastructure by replacing seven legacy systems and developing one division-wide cloud-based solution. Modernization efforts align with Departmental security requirements and create efficiencies within operations by removing stovepipes, strengthening internal controls, and eliminating conflicting functionality. The new division system of record now has the capability to connect and utilize the Departmental data lake, EDAPT platform, and the EDAPT systems, including the Tableau Public Site and Clourdera Platform, to share or transfer public information in a more consumable format to all stakeholders.

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 2021, the grain markets serviced by FGIS represented an approximate value of $120 billion, with exports contributing about $54 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. Its laboratories work with the latest technologies, and through these technologies and ongoing efforts, FGIS is helping to improve the quality of U.S. grain available to the global market. To enhance marketing of grain into the

future, FGIS is also conducting internal research and participating in development and collaborative efforts with other governmental entities, laboratories, and private businesses. The research and analysis it conducts 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 and nuclear magnetic resonance spectroscopy, and improvements in those technologies to meet identified market needs for grain quality assessments.

Current Technology Transfer Initiatives

Inspection Technology Evaluation

In FY 2021, FGIS developed a draft process for evaluating technology for official grain inspection. Technology refers to all equipment, instrumentation, and associated methods for measuring grain quality attributes. A key goal is to provide a transparent process that promotes the adoption of technology that provides accurate and efficient grain inspection results. A first step in the process is to review technology proposals from manufacturers to assess the need and suitability for official grain inspection.

If accepted, the technology is evaluated to confirm that the accuracy requirements are met. The draft process will be shared with the Grain Inspection Advisory Committee to obtain feedback from stakeholders.

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 2021, FGIS conducted 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. The data analysis and final report for the study are expected to be completed in the first quarter of FY 2022. In FY 2021, FGIS initiated a study of 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. This study will be completed in FY 2022.

Rapid Mycotoxin 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 2021, FGIS evaluated 20 test kits and 13 were approved for the detection of mycotoxins in grain including, aflatoxins, deoxynivalenol, fumonisins, and zearalenone. These rapid test

kits facilitate trade by providing cost-effective and accurate technologies to test grain lots in support of contracts between buyers and sellers.

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 methods and has evaluated the accuracy, reliability, and proficiency of publicly available methods used to detect and identify GE grains and oilseeds. FGIS continues to collaborate with international organizations such as Analytical Excellence through Industry Collaboration, International Organization for Standardization, American Association of Cereal Chemists International, The Global Low-level Presence Initiative, and the Canadian Grain Commission to harmonize testing technologies for GE grains and oilseeds.

Pesticide Residue Testing and Method Development

To facilitate trade, FGIS provides pesticide residue testing services, including export surveys, to validate the quality of U.S. grain as it relates to food safety, value, and adherence to U.S. and international regulatory limits. In FY 2021, FGIS analyzed 100 soybean samples, 306 wheat samples, and 130 corn samples for a total of 41,530 pesticide residue results. FGIS' role is critically important as an independent third party and can get samples from the export system to ensure U.S. competitiveness in the global market. In addition, FGIS develops analytical methods to support these activities. FGIS expanded its capability in FY 2021 by modifying existing methods to include the pesticides atrazine, carfentrazone ethyl, chlorpyriphos methyl, and clethodim. FGIS also modified and re-validated five

existing methods using new extraction equipment and instrumentation to increase efficiency and sample throughput.

Leveraging Technology for Outreach

Prior to the coronavirus COVID-19 pandemic, FGIS traveled to other countries to give in-person presentations to explain the U.S. grain standards, to convey the role of FGIS, and to conduct grain grading workshops at the request of USDA Cooperator Organizations. All travel and in-person conferences stopped when the pandemic hit. However, the need remained to educate foreign buyers and answer their questions through seminars and conferences. FGIS and the cooperators began to leverage existing technology like Microsoft Teams and ZOOM to support continued outreach activities. This technology enabled us to reach a wider audience than in-person conferences and reduced costs to the organizers by eliminating travel expenses. FGIS has been using this technology since to hold meetings internally and externally with our stakeholders.

The U.S. Soybean Export Council requested that FGIS present at a virtual 2-day conference in Europe. Several hundred international participants attended virtually. Other cooperator organizations including the U.S. Grains Council and the U.S. Wheat Associates (USWA) also held virtual seminars with FGIS participation.

To make further use of technology, USWA asked FGIS to produce two videos. The first video demonstrates how wheat samples are broken down in a laboratory using FGIS-approved equipment to determine various quality factor results. The second video highlights an FGIS inspector grading various portions. The video includes close-ups of individual types of damaged kernels. FGIS produced the

videos in both English and Spanish. The videos will allow USWA to reduce the seminar time from three to four hours down to just one hour. The videos also allow the audience to virtually experience an actual FGIS inspection lab in operation. A Spanish speaking inspector from FGIS' Board of Appeals and Review gives an opening PowerPoint presentation on the role of FGIS and answers questions after showing the two videos.

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 (AMSA) to conduct in-plant trials and collect data to assess the accuracy of camera instruments in applying the grade standards for beef. As a result, AMSA concluded that the Agency's processes and procedures to ensure the accuracy and integrity of the camera system are robust, and therefore recommended only a few enhancements. Additionally, program specialists conducted 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. 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.

Section 56.3 of the Regulations Governing the Voluntary Grading of Shell Eggs provides for the authorization to conduct experimental work to assess new procedures and advanced technology. Technology associated with egg inspection, including both egg washing and candling, is consistently and systematically improved for inspection and customer applications. In FY 2019, AMS conducted 2,105 inspections with a compliance rate of 97.4 percent to ensure that only eggs fit for human consumption are marketed in consumer outlets. 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.

1.18. Federal-State Marketing Improvement Program (FSMIP)

In FY 2020, AMS received 56 applications from the State departments of agriculture, requesting to implement 687 projects amounting to $72.4 million. Awards were made in September 2020. Funds for this program are awarded through a noncompetitive process in which applications are reviewed to ensure that projects meet the purpose of the program and align with Federal assistance regulations and laws. This review serves as the basis for establishing 3-year grant agreements. Information on the amounts awarded and the projects funded is available on http://www.ams.usda.gov/scbgp.

One project that was completed in FY 2020 came from the Florida Department of Agriculture and Consumer Services, which awarded funding to the University of Central Florida to develop a project that is currently engineering a mechanical arm. This gripper mimics human hands and fingers as it picks strawberries—without damaging the fruit. The technology aims to be universal for different strawberry varieties. The project will also evaluate the economic impact of the gripper creation. The project team

finalized their design and manufactured two prototypes. Both prototypes have gone through laboratory and field tests, and one has been integrated with a robotic arm-like platform for harvesting. The team measures project success by the number of strawberry varieties to which the picking mechanism can be applied and the number of harvesting platforms that decide to adopt the technology.

Another example is a project concluded in FY 2020, where the North Dakota State Department of Agriculture distributed SCBGP funds to North Dakota State University to tackle water management issues. The project's goal was to improve fruit and vegetable yields by creating a drip irrigation system that can be automatically controlled by soil moisture sensors. The project involved experiments to see how different mulch types and amounts impact weed control with the system. The team designed, built, and implemented the drip irrigation system and conducted comparisons on tomato and watermelon yield and quality. Based on the results, they then educated local growers on the new drip irrigation technology. With its projected ability to conserve water, improve soil temperature, and extend growing seasons, the team sees this system as the future of North Dakota specialty crops.

1.19. Specialty Crop Block Grant Program (SCBGP) (Farm Bill Funded)

The Specialty Crop Multi-State Program (SCMP) was authorized by the Specialty Crop Competitiveness Act of 2004 (7 U.S.C. 1621 note), as amended by the Agriculture Improvement Act of 2018 (Public Law 115—334). It provides funds to State departments of agriculture and entities in non-participating States to enhance the competitiveness of specialty crops by funding collaborative, multi-State projects that address regional or national level specialty crop issues. Specialty crops are defined as fruits and vegetables, tree nuts, dried fruits, and nursery crops (including floriculture). SCMP grants are funded from a portion of the SCBGP funds, which remain available until expended.

One project example that will close in FY 2021 comes from the California Department of Food and Agriculture, which partnered with the University of California's Western Institute for Food Safety & Security and Oregon State University to study the role of honeybees in specialty crop production, specifically related to high colony losses. The grant recipient will train veterinarians and apiculture educators to support beekeeper understanding of Veterinary Feed Directive (VFD) complexity in order to maintain strong, healthy colonies for specialty crop pollination and safe honey production. Training will be provided through a comprehensive online bee biology course and train-the-trainer programs. This project has so far been successful in targeting distribution channels for veterinarians which will help the refinement and refocus of the online program to meet specific needs of veterinarians. Standardized hands-on training was developed to provide beginner beekeepers with a tangible and focused training experience.

In another project that will close in FY 2021, the Nebraska Department of Agriculture will partner with the University of Wisconsin and the University of Nebraska to study the marketability of Aronia berry with the goal of increasing small family farm profitability. The grant recipient will characterize the genetic diversity of Aronia produced in the United States and introduce new cultivars with improved characteristics. Researchers will also establish nutritional and flavor benchmarks of Aronia fruit and determine pre-harvest factors associated with improved berry quality. Finally, the project will identify key flavor compounds contributing to the unfavorable taste of Aronia berry and apply food processing technologies to increase consumer preference. So far, 8 of 11 growers were successful in harvesting young shoot tips and submitted them to the Brand lab at the University of Connecticut for DNA extraction. Analysis was completed on grower germplasm. A sample of 1,200 controlled pollinations were conducted to allow associations between multiple Aronia strands. Over 236 progenies have been developed and are being regenerated for further phenotypic and genotypic data collection.

2.0. Animal and Plant Health Inspection Service (APHIS)

2.0.1.   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 – Combined Programs					
		FY 17	FY 18	FY 19	FY 20	FY 21
1	Invention Disclosures Received	4	7	6	4	2
2	Total Patent Applications Filed	5	1	5	7	8
3	U.S.	5	1	5	6	7
4	Foreign	0	0	0	1	2

5	Total PCT Applications Filed	2	0	0	1	0
6	Total Patents Issued	1	1	3	4	5
7	U.S.	1	1	1	2	1
8	Foreign	0	0	2	2	4

Table 2: Licenses – Combined Programs						
		FY 16	FY 17	FY 18	FY 19	FY 20
8	Invention Licenses, Total Active	3	4	4	4	4
9	New Invention Licenses	0	1	0	0	0
10	New Invention Licenses Granted to Small Businesses	0	1	0	0	0
11	Income Bearing Licenses, Total Active	3	4	3	3	3
12	New Income Bearing Licenses	0	1	1	1	0
13	Exclusive, Total Active	0	1	0	0	0
14	Partially Exclusive, Total Active	0	0	0	0	0
15	Nonexclusive, 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	NA	NA	NA	NA	NA
19	Average (months)					
20	Minimum (months)	NA	NA	NA	NA	NA
21	Maximum (months)	NA	NA	NA	NA	NA

22	Licenses Terminated for Cause	NA	NA	NA	NA	NA

Table 3: Income From Licensing – Combined Programs						
		FY 17	FY 18	FY 19	FY 20	FY 21
22	Invention License Income	5,037	375	158	140	13,337
24	Other License Income	0	0	0	0	0
25	Total Earned Royalty Income	5,037	375	158	140	13,337
26	ERI from Top 1% of Licenses	5,037	375	158	140	12,937
27	ERI from Top 5% of Licenses	5,037	375	158	140	12,937
28	ERI from Top 20% of Licenses	5,037	375	158	140	12,937
29	Minimum ERI	37	375	158	240	0
30	Maximum ERI	5,000	375	158	240	12,937
31	Median ERI	NA	NA	NA	NA	NA
	Disposition of ERI	0	0	0	0	0
32	Percentage Distributed to Inventors	49	200	100	100	28
33	Percentage Distributed to Lab/Agency	51	0	0	0	72

Table 4: Collaborative Agreements – Combined Programs						
		FY 17	FY 18	FY 19	FY 20	FY 21
34	Total Active CRADAS	6	7	9	12	10

35	New CRADAs	0	1	3	6	8
36	New CRADAs Involving Small Businesses	0	1	3	2	3
37	Other Collaborative Agreements	217	195	134	516	755

Table 5: Other Intramural Performance Measures Deemed Important to the Agency – Combined Programs						
		FY 17	FY 18	FY 19	FY 20	FY 21
	New Confidentiality Agreements	22	22	12	37	45
	New Material Transfer Agreements	24	24	47	53	49
	New Material Transfer Research Agreements	11	11	15	13	13
	Peer-Reviewed Scientific Publications	141	141	197	178	221
	Nonindexed Publications	20	20	23	11	18

NA = not applicable

2.1. BIOTECHNOLOGY REGULATORY SERVICES (BRS)

2.1.1. Mission Statement

The mission of Biotechnology Regulatory Services (BRS) is to protect and enhance U.S. agricultural and agriculturally important natural resources (the environment) by 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 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 and the environment by overseeing the safe import, interstate movement, and environmental release/field testing of certain organisms developed using genetic engineering. 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 the APHIS biotechnology 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 develop sound quality management practices to enhance their ability to comply with the APHIS biotechnology regulations. The BQMS Program uses a modular system that 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 create a documented self-certifying quality management system to manage critical control points consistent with the requirements of 7 CFR part 340.

Examples of BRS contributions to technology transfer in 2021

In FY 2021, BRS completed the implementation of the revised biotechnology regulations for 7 CFR part 340, which uses science-based and risk-based approaches and are designed to further agriculture innovation and protect plant health and American agriculture. BRS:

- Fostered innovation by completing 6 petitions/extensions seeking a determination of nonregulated status under the legacy regulations; issuing 6 letters confirming that specific modified plants were exempt from regulation; and issuing more than 750 authorizations for regulated activities.

- Assured the safety of sophisticated new technologies by managing more than 22 comprehensive authorizations for the Department of Defense, Defense Advanced Research Projects Agency Insect Allies program, in close coordination with APHIS Plant Protection and Quarantine (PPQ) to ensure effective, efficient, and consistent regulatory oversight. This program completed in FY 2021, funded researchers' development of new approaches for responding to plant stressors in the environment.

- 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, Agricultural Research Service; Environmental Protection Agency; and Food and Drug Administration.

2.2.3. Implementation of the revised biotechnology regulations and impacts on innovation.

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 organisms developed using genetic engineering that pose plausible plant pest risks (7 CFR part 340). APHIS revised its biotechnology regulations in FY 2020 and fully implemented them in FY 2021, to respond to emerging trends in genetic engineering, to use APHIS resources more efficiently and eliminate unnecessary regulatory burdens.

The revisions to 7 CFR part 340 created the framework for more focused, risk-based regulation of organisms developed using genetic engineering that pose a plausible plant pest risk. Under this rule, certain categories of plants are exempted from the regulations in part 340. Developers are able to assess whether their plants meet the criteria for one of the exempt 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 7 CFR part 340. Plants developed using genetic engineering that have 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, though they will they be required to undergo a regulatory status review (RSR). Modified plants that pose a plausible plant pest risk, and modified 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 requesting a review, requesting a permit for the movement (including importation, interstate movement, or environmental release), or doing both. Developers of modified 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 multiyear permits.

The rule became final and effective on May 18, 2020. Since that time, BRS has been working to implement other provisions of the rule. On August 17, 2020, the exemptions took effect and BRS started accepting confirmation requests. Through the end of FY 2021, BRS received 15 confirmation requests and completed a review of 11 requests, of which 6 were confirmed. On April 5, 2021, BRS began accepting RSR requests for six crops (corn, soybean, cotton, potato, tomato, and alfalfa) and the new

permitting regulations took effect. As of October 1, 2021, the RSR process is fully implemented and petitions for deregulation are no longer accepted.

One of the expected outcomes from the revised regulation is an increase in innovation that will ultimately benefit developers, producers, and consumers of certain organisms developed using genetic engineering. In the short time that the revised rule has been implemented, BRS is seeing a marked increase in innovation based on several metrics: the number of requests from companies that never submitted a petition (67 percent of the confirmation requests and over 50 percent of the RSR requests); the number of requests for species that were never the subject of a petition (33 percent of the confirmation requests);[1] and requests for traits other than herbicide resistance and insect resistance (73 percent of the confirmation requests and over 80 percent of the RSR requests). To give some perspective to the last metric, under the petition process, only 40 percent of the petition requests had traits other than herbicide or insect resistance.

USDA has taken an active role in disseminating information about the revised regulations, including conducting stakeholder meetings to discuss guidance for regulatory exemptions/confirmation requisitions and the RSR process. USDA has also published a peer review article in Proceedings of the National Academy of Science describing the revised regulation.[2]

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[1] Through FY2021, only species that had previously been the subject of a petition were eligible for RSR. Starting in FY2022, all plant species will eligible for RSR.

[2] Hoffman, N.E. (2021). Revisions to USDA biotechnology regulations: The SECURE rule. *Proceedings of the National Academy of Sciences* 118**,** e2004841118.

Confirmed Requests	15 (6 confirmed)
Requests from companies that never submitted a petition	10 (4 confirmed)
Requests for species never the subject of a petition	5 (2 confirmed)
Requests for traits other than insect resistance and herbicide resistance	11 (4 confirmed)

2.2.   INTERNATIONAL SERVICES

2.3.1. 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.

2.3.2. Nature and Structure of the Program

IS' overseas presence enables 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 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 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:

- In 2021, the Action Programs Medfly/Mexfly (MOSCAMED) Program provided 35,000 insecticide impregnated wax bait stations, a tool developed and tested in Guatemala and approved by the U.S. Environmental Protection Agency for use in Texas, for a Mexican fruit fly eradication program in southern Texas.

- MOSCAMED supported the development of a collaboration between itself, Popoyan, an agricultural industry group in Guatemala, and IAEA to train growers on control of the Mediterranean fruit fly and demonstrate increased quantity and quality of harvests when the pest is effectively managed.

- In 2021, MOSCAMED funded and oversaw the establishment of a bee center in northwest Guatemala, assisted with the importation of genetically improved queen bees for apiaries, as well as worked with industry, commodity associations, and nongovernmental entities to gain access for activities necessary to the management of Mediterranean fruit fly. Through this program, MOSCAMED gained access to 168 hectares (415 acres) in strategic work areas for conducting Medfly-related detection and control activities.

- During 2021, IS personnel from the Panama-United States Commission for the Eradication and Prevention of Screwworm (COPEG), continued to transfer technology and protocols to USDA, ARS scientists in cryopreservation and collection of genetic material in the field. Additionally, genetic material collected from the laboratory and the field was transferred to ARS to assist with research and development. 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. Future advancement in research and development of technology to improve screwworm control relies on cataloguing and retrieval of preserved and banked genetic diversity.

- COPEG personnel continue to serve as a resource and facilitator in the development and transfer of technology, protocols, education, and training cooperatively to international organizations and countries interested in pursuing SIT as an option for safeguarding against transboundary pests and diseases.

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

- In 2021, COPEG continued technology transfer (protocols and information) to Uruguay which is close to finalizing plans for a screwworm eradication program in 2022.

Caribbean

In 2021, 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 outbreak of African swine fever in the Dominican Republic and Haiti was first detected due to samples analyzed by the Foreign Animal Disease Diagnostic Laboratory (FADDL) at Plum Island, NY. APHIS has so far donated approximately $500,000 in equipment and supplies to the Dominican Republic's National Veterinary Laboratory (LAVECEN) and continues to support the laboratory with temporary duty staff from FADDL and National Veterinary Services Laboratory (NVSL) to provide training and assistance with the new equipment. Thanks to APHIS assistance, LAVECEN has greatly increased its capacity to process samples for ASF surveillance and detection. Although ASF is currently the main concern,

APHIS assistance to LAVECEN has also improved the laboratory's capacity to process samples for other diseases such as classical swine fever and avian influenza.

- Support CaribVet efforts to strengthen avian influenza surveillance and risk mapping activities in the Caribbean region.

- Support for training and strengthening of the network of diagnostic laboratories (RESUDIA) in South America.

- Conduct training and activities for emergency planning and preparedness, such as recent Good Emergency Management Practices (GEMP) training in Colombia, throughout all of the Latin American countries.

Mexico

- In FY 2020, APHIS–VS continues to support officials from the Mexican National Animal Health Laboratory through NVSL on Whole Genome Sequencing of *M. bovis* and the associated bioinformatics.

- In FY 2021, APHIS–VS assisted Mexico in modernizing cattle identification systems, including greater use of RFID (radio frequency identification) tags. This technology allows for more efficient and accurate accounting of cattle herds, including those that cross the Mexican border into the United States.

- In FY 2021, APHIS–WS supported Mexico's efforts to control and monitor hemorrhagic viruses, COVID-19, and rabies, in both wildlife and domestic animal populations, by supplying expertise and essential biologics, including vaccines, primers, and reagents. APHIS–WS also supplied technology platforms to facilitate meetings, trainings and seminars related to feral swine and porcine diseases, including African swine fever.

South Asia Region

Philippines

- Veterinary Diagnostics Laboratory Quality Assurance (VDLQA) Symposium. Ensured participation from Philippines and Malaysia in the VDLQA which was convened virtually in spring 2021.

Vietnam

- In FY 2021 APHIS–IS worked to coordinate vaccine technology transfer from the USDA, ARS (Agricultural Research Service) to Vietnamese commercial and government partners. APHIS–IS coordinated a trip and facilitated communications resulting in the transfer of two African swine fever (ASF) vaccine candidates for development, registration, and implementation of a vaccine for ASF. ASF has devastated swine resulting in the culling of 20 percent of Vietnam's commercial swine herd in 2019. Preliminary results of the vaccine show protection from the virus and commercial production is expected in FY 2022. A successful ASF vaccine will have a significant and positive global impact restoring safe swine trade.

Thailand

- In FY 2021, APHIS–IS collaborated with Purdue University and Kansas State University to provide a 4-day virtual workshop which provided information and technical assistance on the management and resolution of outbreaks of African swine fever virus (ASFV). Topics in the workshop included, but were not limited to, regulatory consequences of ASFV diagnosis, available diagnostic tools, biosecurity practices, outbreak response strategies, and future vaccine and treatment developments. Over 100 veterinary professionals from 13 countries across Asia attended the workshop.

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, Department of Energy National Labs, Department of Homeland Security, and Environmental Protection Agency, 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.

2.3.3. Current Technology Transfer Goals, Objectives, and Measures of Success

PPQ is committed to the 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 in Maryland 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 potatoes, and roses.

Table 1: Disclosures and Patenting – Plant Protection and Quarantine		FY 16	FY 17	FY 18	FY 19	FY 20
1	Invention Disclosures Received	0	0	0	0	0
2	Total Patent Applications Filed	0	0	0	0	0
3	U.S.	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	U.S.	0	0	0	0	0
8	Foreign	0	0	0	0	0

Table 2: Licenses – Plant Protection and Quarantine		FY 16	FY 17	FY 18	FY 19	FY 20
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	1	1	1
13	Exclusive, Total Active	0	0	1	0	0
14	Partially Exclusive, Total Active	0	0	0	0	0
15	Nonexclusive, 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
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						
		FY 16	FY 17	FY 18	FY 19	FY 20
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	NA	NA	NA	NA	NA

		FY 16		FY 18		
	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						
		FY 16	FY 17	FY 18	FY 19	FY 20
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	ND

Table 5: Other Intramural Performance Measures Deemed Important to the Agency – Plant Protection and Quarantine					
	FY 16	FY 17	FY 18	FY 19	FY 20
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
Nonindexed Publications	ND	ND	ND	ND	ND

NA = not applicable. ND = not determined.

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 FY 20, over 100 of the program's identification products are available via an open-access searchable portal (https://idtools.org). New releases in FY 20 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; 6 new fact sheets for the Grasshoppers of the Western United States 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 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, who 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 4 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 1 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 the 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 Dept. 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 United States, but also prepared the U.S. 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

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 Organization 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, 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 (VSTA) 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

•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		FY 17	FY 18	FY 19	FY 20	FY 21
1	Invention Disclosures Received	0	0	0	0	0
2	Total Patent Applications Filed	0	0	0	0	0
3	U.S.	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	U.S.	0	0	0	0	0
8	Foreign	0	0	0	0	0

Table 2: Licenses – Veterinary Services		FY 17	FY 18	FY 19	FY 20	FY 21
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	Nonexclusive, 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

ND = not determined

Table 3: Income from Licensing – Veterinary Services		FY 17	FY 18	FY 19	FY 20	FY 21
22	Invention License Income	$0	$0	$0	$0	$0
24	Other License Income	$0	$0	$0	$0	$0
25	Total Earned Royalty Income (ERI)	$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		FY 17	FY 18	FY 19	FY 20	FY 21
34	Total Active CRADAs	0	0	0	1	0
35	New CRADAs	0	0	0	1	0
36	New CRADAS Involving Small Businesses	0	0	0	1	0
37	Other Collaborative Agreements[3]	32	41	63	149	405

³ Includes Trust Fund Agreements, Interagency Agreements, Cooperative Agreements, Cooperative Service (Reimbursable) Agreements, Non-Funded Cooperative Agreements, and Memorandum of Understandings.

Table 5: Other Intramural Performance Measures Deemed Important to the Agency – Veterinary Services						
		FY 17	FY 18	FY 19	FY 20	FY 21
	New Confidentiality Agreements	17	3	29	35	19
	New Material Transfer Agreements	17	35	44	37	48
	New Material Transfer Research Agreements	5	0	0	6	18
	Peer-Reviewed Scientific Publications	33	22	56	74	59
	Nonindexed Publications	0	0	0	0	1

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 published Center for Veterinary Biologics Notice 20-12, informing interested parties that they are accepting veterinary biologics product license and permit applications for veterinary biological products used to vaccinate mink against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) the etiologic agent of coronavirus disease 2019 (COVID-19).

- VS participated, virtually, in the American Veterinary Medical Association Council on Biologics and Therapeutic Agents and Clinical Practitioners Advisory Committee meeting. The agenda included information on current/emerging biologics and therapeutic issues.

- VS participated, virtually, in the United States Animal Health Association and the Annual Meeting of the American Association of Veterinary Laboratory Diagnosticians.

- VS participated, virtually, in the open sessions of the Association of Veterinary Biologics Companies (AVBC) meeting. At this meeting the AVBC members collaborate with VS staff and share various presentations on ongoing initiatives on current biologics topics.

- VS participated in the 2021 Iowa State University James D. McKean Swine Disease Conference: The conference included lectures regarding porcine reproductive and respiratory syndrome, biosecurity, African swine fever, porcine astrovirus, *Streptococcus suis*, and a One Health approach to antimicrobial resistance.

- VS participated in the 45th Annual International Good Manufacturing Practices (GMP) Conference with a VS subject matter expert presenting, *Principles and Practices of Good Manufacturing as Required by the Virus-Serum-Toxin Act*. The conference included sessions on GMP Inspection Recognition and Reliance, Remote Auditing, Sterility Assurance, Post-Approval Change Management, GMP Challenges in Animal Health Products, along with many updates on inspection trends and updates on new guidance documents.

- VS participated in the National Veterinary Stockpile Intra-Governmental Advisory Committee for Strategic Steering. During the vaccine updates portion of the meeting the VS participant provided a presentation on classical swine fever vaccine updates.

- VS participated in a virtual meeting with representatives from the National Milk Producers Federation to discuss record keeping requirements associated with the use of veterinary vaccines and immunotherapeutics.

- VS participated in a virtual meeting with American Association of Swine Veterinarians' Committee on Transboundary and Emerging Diseases.

- VS participated in the American Association of Swine Veterinarians' Committee on Influenza.

- VS, in conjunction with Iowa State University, provided a four-session Quantitative Polymerase Chain Reaction Seminar Series.

- VS participated in the USDA and Agricultural Research Service, 6th International Biosafety & Biocontainment Symposium, titled, *Emerging Biorisk Challenges in Agriculture*. VS presented at a workshop on *Managing Research Safety During Pandemic Conditions*. Sessions included: African swine fever, applied biosafety research and international effort, and emerging issues.

- VS participated in the Iowa Veterinary Medical Association Conference. Some of the agenda items included USDA African Swine Fever Exercises Update and Practical Applications, Sample Validations for Foreign Animal Diseases, African Swine Fever, Strain Differences and

Virulence, Overview of the Secure Beef Supply Program, USDA Update on Animal Disease Traceability, and Advancing Herd Performance and Immunity with New Considerations Regarding Calving and Colostrum Management in Cow Calf Operations. Additionally, many topics on equine, companion animals, and animal welfare were on the agenda.

- VS participated in the *Systematizing the One Health Approach in Preparedness and Response Efforts for Infectious Disease Outbreaks: A Virtual Workshop.* The National Academies' Forum on Microbial Threats hosted this virtual workshop to examine ways to systemize and integrate the One-Health approach as part of outbreak prevention, detection, preparedness, and response efforts. This workshop explored multisector collaboration mechanisms, community engagement strategies, workforce development, and policies that can effectively implement the core capacities and interventions of One Health principles.

- VS participated in meetings of the Animal Health Institute (AHI), Veterinary Biologicals Section (VBS). VS representatives met with AHI members in several working group sessions, as well as participated in the general session to provide updates on current projects and initiatives at the USDA, Center for Veterinary Biologics. Additionally, staff met with the VBS Steering Committee to provide insight into current initiatives and further collaborative discussion with industry.

- VS participated in a virtual workshop titled: "Novel *In-Vitro* Model as Alternative to *In-Vivo* Toxoid Vaccines Testing: *Clostridium Septicum* Vaccine as Proof of Concept." The event was hosted by the European Directorate for the Quality of Medicines & HealthCare, Council of Europe, the European Partnership for Alternative Approaches to Animal Testing and the

European Commission and was attended by European regulators and industry representatives. The VS subject matter expert provided a brief overview of the regulatory testing of toxoid vaccines at the CVB while emphasizing the *in vitro* options available to veterinary biologics manufacturers once validated for their products.

- VS subject matter experts held a virtual meeting with The Roslin Institute and Royal (Dick) School of Veterinary Studies, University of Edinburg, Scotland, to discuss porcine circovirus and vaccine needs for the swine industry.

- A VS subject matter expert provided prerecorded presentations on topics regarding the regulation of veterinary biologics at the virtual meeting of the 2021 Student American Veterinary Medical Association Symposium.

- VS attended the 2021 International Society for Pharmaceutical Engineering Global Pharmaceutical Regulatory Summit–Remote/Distant Assessments, Audits, and Regulatory Guidance. Speakers from the U.S. Food and Drug Administration, European Medicines Agency, and Pharmaceutical Inspection Co-Operations Scheme presented guidance used to ease the impact of disruptions caused by COVID-19 and the difficulty of onsite inspections during the pandemic. The benefits and pitfalls to remote audits were discussed. Interacting with like regulatory agencies regarding best practices and limitations of remote inspections allows VS to continue to implement policies and practices to effectively achieve the mission.

- A VS subject matter expert gave a virtual presentation at the International Society for BioProcess Technology 2021 Virtual Convention. The presentation was titled, "Ensuring That APHIS

Licensed Equine Plasma or Serum Veterinary Biologic Products are Negative for Equine Parvovirus-Hepatitis." The presentation had been requested by the Containment Control Chair for the Convention.

- VS participated in the Virtual Transatlantic Taskforce on Antimicrobial Resistance (TATFAR) meeting. The meeting included member representatives and implementers of the TATFAR from the European Union, United States, Norway, Canada, and the United Kingdom, as well as key partners on global antimicrobial resistance (AMR). The meeting objectives were assessing TATFAR's work to date, exchanging views on other international AMR initiatives, and shaping TATFAR's future work.

- VS participated in the USDA-sponsored virtual Scialog: Mitigating Zoonotic Threats. The workshop brought together 50 early-career scientists from various disciplines to form multidisciplinary teams and obtain funding to tackle critical zoonotic disease challenges.

- VS personnel participated at the 6th Vietnam One Health Biorisk Management Case-Based Learning Remote Engagement as a speaker and panelist. The event was organized on behalf of the Vietnam One Health University Network and in collaboration with the U.S. Department of Defense Biological Threat Reduction Program, Sandia National Laboratories, Vietnam Ministry of Health, General Department of Preventive Medicine, and Ministry of Agriculture and Rural Development, Department of Animal Health.

- VS personnel participated in Technical Consultations for African Swine Fever meeting, providing technical consultations for African swine fever with Meghalaya, India, government

health officials. The meeting was organized by the International Technical and Regulatory Capacity Building unit of International Services of USDA, APHIS.

- VS personnel attended the European Union Reference Laboratory for Fish and Crustacean Diseases Compendium on Diagnostic Techniques for Viral Fish Diseases and served as an external advisor for the first virtual offering of this annual course. The focus of this training is on methods for implementation of surveillance procedures for EU and OIE listed fish diseases. Topics covered included the legislative basis for fish health management and animal health law in the EU, sampling procedures for surveying listed fish diseases, use of cell culture for surveying for fish diseases, molecular methods and bioinformatics utilized to identify and detect listed fish diseases.

- VS earned official designation from the Food and Agriculture Organization of the United Nations (FAO) as a "FAO Reference Centre for Diagnostics of Rinderpest," The designation is for a 4-year period and complements VS' status as a World Organization for Animal Health (OIE) Rinderpest Reference Laboratory and a FAO-OIE Rinderpest Holding Facility.

- VS personnel participated in a meeting with the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) to discuss reference laboratory testing for dourine. VS personnel presented recent data showing the performance of several lots of dourine antigen produced by the NVSL, discussed antigen production methods, and compared complement fixation antigen titration protocols. Difficulties in obtaining and curating a serum bank were also discussed with both labs acknowledging that serum from natural infections would be ideal. ANSES is hopeful that their new role as the OIE reference lab may help provide an avenue to

obtain such samples.

- VS personnel attended a meeting with Statnes Serum Institut in Denmark regarding analysis of data from the recent Danish Contagious Equine Metritis outbreak and the potential for future collaborative work on *Taylorella equigenitalis*. Whole genome sequence data of *Taylorella equigenitalis* generated by the NVSL was used to establish a general SNP distance measure of "closely" related for comparison to Danish sequences. Going forward, Denmark would like to establish a direct PCR for use as their primary diagnostic tool for screening horses and plan to carry out a study next year to survey the domestic Danish horse population and compare direct PCR and culture results.

- VS personnel hosted a meeting with the national reference laboratory in Chile (Servicio Agricola y Ganadero (SAG)–Agricultural and Livestock Service) on assessment and support of molecular diagnostic testing for avian influenza and Newcastle disease. VS laboratories have maintained a longstanding relationship with SAG over the years in support of the detection and diagnosis of avian influenza and Newcastle disease, partnering with them for an OIE twinning, and ongoing support to RESUDIA, the laboratory network in South America. Diagnostic sample workflows were reviewed during the meeting, and structured discussions regarding virus isolation, serology, and molecular/sequencing activities were held. Afteraction items include sharing of current protocols and troubleshooting issues with the neuraminidase inhibition reagents purchased from NVSL. SAG personnel are interested to learn more from our National Poultry Improvement Program colleagues on how they manage proficiency testing of the network labs.

- VS personnel have served as subject matter experts on the SARS-CoV-2 Interagency Risk

Assessment Meeting (SCIRAM). The SCIRAM is charged with improving the process for tracking the evolution of SARS-CoV-2 and scientifically evaluating the changes that may be relevant for diagnostic assays, vaccines, or therapeutics to enhance the agility and effectiveness of the United States to respond to the COVID-19 pandemic. The SCIRAM has six key working groups: (1) Genomic Surveillance & Bioinformatics Working Group (NVSL Director Dr. Robbe-Austerman is co-chairing), (2) Virus Characterization & Pathogenesis Working Group, (3) Diagnostics Working Group, (4) Vaccines Working Group, (5) Therapeutics Working Group, and (6) One Health Genomics Working Group.

- VS personnel have served as co-lead for the SARS-CoV-2 One Health Genomics Working Group, one of six working groups of the SCIRAM. The genomics working group is charged with monitoring SARS-CoV-2 outbreaks and emergence of new viral strains and mutations of concern through One Health investigations that involve linked human and animal cases to understand the transmission dynamics in animal populations and between human and animal populations; the risks associated with host shift events in the emergence of new viral strains; the research and science needed to evaluate how the zoonotic nature of SARS-CoV-2 will impact human and animal populations; and other relevant topics as needs arise.

- VS personnel have collaborated with the Canadian Food Inspection Agency (CFIA) regarding development and harmonization of glanders diagnostic reagents. This collaboration is part of a larger VS effort to improve equine import testing. VS shared its current status of glanders antigen production, which is in the proof-of-concept agent inactivation phase; and CFIA confirmed that they use an analogous (nearly identical) inactivation procedure. Both VS and CFIA recognized the extreme limitation of available samples of glanders serum. VS personnel

presented on the status of a collaboration with the German Friedrich Loeffler Institute (FLI), whereby VS has sent equipment, reagents, and a small set of samples to FLI to have them evaluate a western blot platform and complement fixation protocol with FLI's large serum bank. CFIA presented their progress on whole genome sequencing and comparisons of various strains of the glanders bacteria with a goal of selecting potential protein targets that are common among the strains, which could then be used as targets for development of recombinant proteins for serological assays.

- VS personnel have developed and prepared Bluetongue virus (BTV) real-time RT-PCR (rRT-PCR) Proficiency Test (PT) panels, the first time a BTV rRT-PCR PT panel was made in VS. PT panels are used to demonstrate competency of individual operators regarding specific testing quality and technical performance of the assay. BTV causes a viral disease affecting domestic and wild ruminants. BT is a disease listed under the OIE Terrestrial Animal Health Code and must be reported to the OIE. In countries where BTV is endemic the impact is largely on loss of trade due to restrictions and the costs of surveillance, health testing, and vaccination.

- VS personnel participated on a One Health team comprised of representatives from the Centers for Disease Control and Prevention, ARS, the APHIS Wildlife Services to conduct a Leptospira surveillance study in Puerto Rico. The study objective is to better understand transmission of pathogenic leptospires from wildlife to humans following the devastation resulting from Hurricane Maria. The plan is to also survey wildlife and to look at veterinary clinical cases of leptospirosis. Results should provide information on Leptospira prevalence and the animal sources of human cases.

- VS published their first Tableau dashboards on antimicrobial resistance which are accessible to the public on USDA websites. Tableau dashboards provide users with interactive features to explore patterns and drill into details, while controlling what data are displayed and can be downloaded. Additionally, the data-based figures can be modified by updating the underlying data, automating what were previously manual and time-consuming report preparation tasks. The AMR dashboard is visible at https://www.aphis.usda.gov/aphis/dashboards/tableau/amr.

- VS published a Tableau dashboard on SARS-CoV2 confirmed cases in animals in the United States which is accessible to the public on USDA websites. The content for SARS-CoV2 confirmed cases in animals in the United States is visible at https://www.aphis.usda.gov/aphis/dashboards/tableau/sars-dashboard. To date, 14 different animal species have been reported to be infected with SARS-CoV-2. The USDA National Veterinary Services Laboratories is responsible for conducting confirmatory testing, and for coordinating the numbers of animals tested.

- VS personnel have participated and presented in a variety of scientific meetings of the Biosafety Level 4 Zoonotic Laboratory Network (BSL4ZNet). The BSL4ZNet was established in 2016 as a network of animal and public health organizations from five countries, including Australia, Canada, Germany, the United Kingdom, and the United States. The BSL4ZNet was established to respond to current and emerging high-consequence bio-threats through strong international partnerships, institutional cooperation and knowledge sharing, and scientific excellence and training in the global high-containment laboratory community. The Network is currently coordinated by the Office of the Chief Science Operating Officer, Science Branch, CFIA, Canada.

- VA personnel participated in a technical meeting with the African Center of Excellence for Genomics of Infectious Diseases (ACEGID) to facilitate the transfer of NVSL's Foreign Animal Disease Diagnostic Laboratory's ASF–FAST technology to the ACEGID. The meeting discussed a broad range of technical issues including sample types, bioinformatics, and software capabilities needed for the technology transfer. VS personnel have provided the following: the ASF–FAST published article, genome sequencing protocols, list of consumables and reagents, and a brief presentation of the ASF–FAST technology. Bioinformatics teams of both institutions will meet to assess existing capacity at ACEGID for data analysis including potential internet connectivity issues to facilitate virtual trainings and the information transfer process.

- VS personnel participated in an interlaboratory assessment of molecular diagnostic assays identified for the detection of tilapia lake virus (TiLV). The OIE Collaborating Centre for New and Emerging Diseases and Test Validation Science (CSIRO, Australian Centre for Disease Preparedness (ACDP)), under the Terms of Reference for the ad hoc Group on TiLV, produced a rigorous panel that was shipped to nominated laboratories to evaluate three real-time based assays (two probe-based and one SYBR assay) and a conventional seminested assay. Participating laboratories were also encouraged to also evaluate any in-house assay against the panel.

- VS personnel from the NVSL's Aquaculture Section delivered a virtual training course to USDA veterinarians that provided participants with the information and training needed to conduct inspections and lead investigations at U.S. production facilities when an aquatic pathogen, foreign or domestic, is suspected in a disease event. Participants included APHIS Port Veterinarians and Veterinary Medical Officers (VMO) representing all districts across the United

States and two VMOs from outside VS' Field Operations. In previous years, the course has been held in-person to benefit from the wet laboratory which provides opportunity to observe disease signs in clinically infected fish and onsite farm tours but was held in a virtual format to accommodate for COVID-related restrictions. VS presenters provided subject matter expertise on diseases of finfish, mollusks, and crustaceans.

- VS personnel presented at the 10th Meeting of the Latin American Society of Tuberculosis and other Mycobacteriosis on *Mycobacterium bovis* infection of livestock and wildlife in the United States.

- VS personnel participated in the Spatial Biology Europe Virtual Conference. The conference addressed use of spatial biology technology for gene expression and protein expression in tissue sections for a better understanding of molecular profiles associated with different diseases and cancers and the study of viral-host interactions.

- VS has established bilateral cooperative agreements with Honduras, Costa Rica, and Guatemala as part of the world *M. bovis* characterization project to obtain representative samples from Central America. Secondary objectives for these agreements involve improving Central American laboratory capacity by providing training on diagnostic procedures for bovine tuberculosis, including a focus on bacteriologic and molecular procedures such as isolation of *M. bovis* on solid media, sample processing for direct PCR for detection of *M. bovis* directly from tissue, acid-fast staining, tube reading, mycobacterial DNA extraction, and real time PCR.

- VS personnel worked collaboratively with PPQ personnel to write a chapter for a textbook

devoted to tactical considerations for animal and plant health emergencies. The chapter explores

the beginnings of APHIS and aspects of emergency response related to animal and plant health

emergencies, including similarities and difference between the two types. This chapter includes

historical perspectives on animal and plant health responses through the years and outlines the

roles that APHIS plays in the national response to animal and plant health emergencies. This

chapter also includes the regulatory authorities under which APHIS works. There are also

references to the National Incident Management System and the legal framework required to

operate within this and other systems. This chapter gives a very brief overview to the Incident

Command System but provides specific and unique positions related to animal and plant health

emergencies. Additional information is provided through plant and animal health program case

studies which provide details related to specific animal and plant health emergencies over time.

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 dynamic and mobile, and can damage agricultural and industrial resources, pose risks to human health and safety, and affect other natural resources. WS is the Federal program responsible for helping to solve problems that occur when human activity and wildlife 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 WS. NWRC is the only Federal Laboratory devoted to resolving problems caused by wild animals.

Based at the Foothills Campus of Colorado State University in Fort Collins, CO, the NWRC employs more than 150 scientists, technicians, and support personnel at its headquarters campus and at 7 field stations 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 provides the ability to address regional wildlife damage management issues. NWRC routinely conducts international consultations in this specialized area.

Scientists at NWRC apply diverse ability to the development of practical, biologically, environmentally, and socially sound methods resolving problems and maintaining the quality of the environment shared with wildlife. NWRC scientists specialize in many disciplines, including animal behavior/psychology, chemistry, biology, ecology, zoology, economics, genetics, immunology, pharmacology/toxicology, physiology, wildlife biology, and wildlife disease. NWRC collaborates with university, not-for-profit research facilities and other public and private entity experts with different specialties.

WS works within the USDA One Health approach which embraces the idea that complex problems that affect the health of humans, animals, and the environment are best solved through improved communication, cooperation, and collaboration across disciplines and sectors (https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/sa_one_health). NWRC develops effective wildlife damage management methods through contributions in the following areas:

- Wildlife damage assessment

- Investigation of the biology and behavior of animals associated with damage

- Evaluation of the impact of damage management practices on wildlife and the environment

- Development and improvement of existing damage management technologies

- Investigation of potential applications of new damage management technologies

- Support for registration of chemicals, drugs, and devices used to manage wildlife damage

- 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

NWRC follows specific criteria striving toward tools and techniques that select for the problem species, are socially responsible, present as little environmental impact when employed, are cost effective, and when needed, receive regulatory approval and oversight. These criteria guide NWRC's work ensuring the acceptance and adoption of products and techniques by industry regardless of the method NWRC develops.

The NWRC works under a "pipeline" workflow model (Figure X), originating with ideas from NWRC, WS Operations, or outside entities and culminates with a useful tool and/or technique. A key step in this pipeline is finding private or university partners to collaborate with product development, taking the technology to a marketable product. Partnering can take a variety of forms including formal developmental technology transfer agreements through patenting and licensing.

Figure X: NWRC Product Development Pipeline
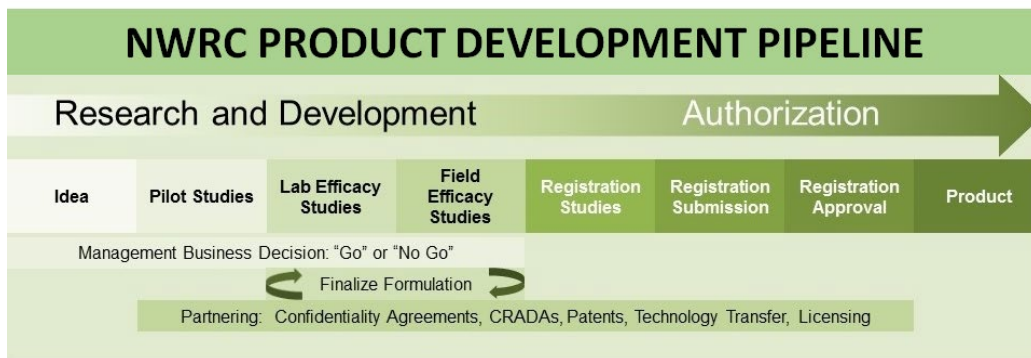
Examples of this workflow model can be found in almost all WS product development projects. An idea for an avian contraceptive was originally brought to the NWRC by a private party who wondered if a negative side effect of a coccidiostat commonly used by the poultry industry could be turned into a contraceptive for managing overabundant birds. This product is currently marketed under the tradename OvoControl™. An NWRC biologist developed a novel live trap for capturing large invasive snakes in the Everglades. This trap is now available for purchase through Tomahawk Live Trap. NWRC is currently pioneering rodenticide development research around the use of genetic sequences that could inhibit protein synthesis by interfering ribonucleic acid (i-RNA). By design this tool could be species specific, thereby reducing risk to nontarget organisms and the environment. When developed, this technology will be available to the private companies for manufacture and sale.

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

WS follows the 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 benefiting the Nation by increasing productivity and efficiency (keeping costs low) and enhancing global competitiveness for the U.S. agricultural sector. Technology transfer is critical to accelerating the use of public research and methods development, creating economic activity and jobs, and sustaining economic development.

WS uses Confidentiality Agreements (CA), Material Transfer Agreements (MTA), Material Transfer Research Agreements (MTRA), and Cooperative Research and Development Agreements (CRADA) for technology transfer. WS transfers technology through patents and invention licenses for commercialization by the private sector. WS has a formal agreement with USDA, Forest Service's

Technology Transfer office (USFS) helping with the preparation of Intellectual Property Agreements and Patents. USDA, ARS Office of Technology Transfer (ARS–OTT) arranges the licensing of NWRC patented intellectual property. NWRC's Technology Transfer Program Manager is the liaison for APHIS to the USFS and ARS–OTT.

WS transfers knowledge and technology through other formal and informal mechanisms. The primary method for NWRC scientists is publication in peer-reviewed scientific journals. Other mechanisms for transferring technology and knowledge include presentations at technical or professional conferences, 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 has staff dedicated to the registration and 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. Developed products continue through the research and development pipeline and registration process with the regulatory agencies (Figure X). WS Pocatello Supply Depot produces and distributes products with limited private market potential and considered necessary for WS mission operations. WS Pocatello Supply Depot licenses products with significant private market potential for sale to private companies. Efforts to increase the number of APHIS products licensed by private companies include patenting innovative technology, developing CRADAs and Material Transfer Research Agreements, participating in regional technology development functions, participating with the Federal Laboratory Consortium, interacting with national, State, and local governments, universities, industries, and enhancing training for NWRC scientists in technology transfer.

NWRC measures success of its technology transfer efforts through publication success (Figure XX). In FY 21, NWRC scientist published 83 peer-reviewed manuscripts and 18 trade nonindexed publications or book chapters. Since 2006 when NWRC began tracking web-based publication downloads the number of annual downloads increased each year. Since 2017, outside entities downloaded NWRC publications over 915,000 times.

Figure XX: Wildlife Service Publication Activity

Publication Outlet	FY 17	FY 18	FY 19	FY 20	FY 21
WS Publications					165
WS Operations Publications	-	-	-	-	13
NWRC Publications	128	175	133	123	152
Publication Outlets					
Peer-Reviewed Journals	68	85	76	65	83
Nonpeer-Reviewed Journals	5	7	0	6	6
Book Chapters	7	16	11	11	13
Monographs/Book	-	-	-	1	1
Technical Reports	-	-	-	-	1
Average JIF Score[†] (NWRC Publications)					3.61
Publication Downloads	133,693	131,126	126,912	172,695	175,617
[†] Journal Impact Factor (JIF) is calculated by Clarivate Analytics as the average of the sum of the citations received each year to a journal's previous 2 years of publications divided by the sum of "citable" publications in the previous 2 years.					

NWRC also measures technology transfer and research development efforts through the number of collaborators. NWRC partners with 150 individual institutions annually including universities, State and local governments, and private partners. NWRC scientists and staff collaborate with 20 foreign governments or institutions annually.

NWRC tracks the number and monetary value of all types of agreements increasing efforts for more cooperator funding. Incoming and outgoing cooperator funding is an important means of developing and

transferring NWRC technology to universities and private collaborators. In 2021, NWRC entered into a total of 75 funding transfer agreements (Figure XXX).

Figure XXX: FY 2021 NWRC Agreement Financials

Type	#	Total
Cooperative Agreements	49	$3,497,172.92
Cooperative Service Agreements	13	$ 620,801.12
CRADA	3	$14,000.00
Interagency Agreements		
Incoming Funding	13	$2,130,387.55
Outgoing Funding	0	
Grants	0	
TOTALS	75	$7,724,385.04
Total Incoming Funding		$2,765,188.67
Total Outgoing Funding		$3,497,172.92

2.5.4. Combined Metric Tables

Table 1: Disclosures and Patenting – Wildlife Services					
		FY 17	FY 18	FY 19	FY 20	FY 21
1	Invention Disclosures Received	4	4	6	3	1
2	Total Patent Applications Filed	5	0	5	5	8
3	U.S.	5	0	5	4	7
4	Foreign	0	0	0	1	2
5	Total PCT Applications Filed	2	0	0	1	0
6	Total Patents Issued	1	1	3	4	5
7	U.S.	1	1	1	2	1
8	Foreign	0	0	2	2	4

Table 2: Licenses – Wildlife Services					
		FY 17	FY 18	FY 19	FY 20	FY 21
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	Nonexclusive, 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)	NA	NA	NA	NA	NA
20	Minimum (months)	NA	NA	NA	NA	NA
21	Maximum (months)	NA	NA	NA	NA	NA
22	Licenses Terminated for Cause	NA	NA	NA	NA	NA

Table 3: Income from Licensing – Wildlife Services						
		FY 17	FY 18	FY 19	FY 20	FY 21
22	Invention License Income	$25	$158	$140	$100	$12,937
24	Other License Income	0	0	0	0	0
25	Total Earned Royalty Income	$25	$158	$140	$100	$12,937
26	ERI from Top 1% of Licenses	$25	$158	$140	$100	$12,937
27	ERI from Top 5% of Licenses	$25	$158	$140	$100	$12,937
28	ERI from Top 20% of Licenses	$25	$158	$140	$100	$12,937
29	Minimum ERI	$25	$158	$240	$100	$0
30	Maximum ERI	$25	$158	$240	$100	$12,937
31	Median ERI	NA	NA	NA	NA	NA
	Disposition of ERI					
32	Percentage Distributed to Inventors	100	100	100	100	28
33	Percentage Distributed to Lab/Agency	0	0	0	0	72

Table 4: Collaborative Agreements – Wildlife Services						
		FY 17	FY 18	FY 19	FY 20	FY 21
34	Total Active CRADAs	6	7	9	11	10
35	New CRADAs	0	1	3	3	3

36	New CRADAs Involving Small Businesses	0	1	3	1	3
37	Other Collaborative Agreements	185	154	171	85	72

Table 5: Other Intramural Performance Measures Deemed Important to the Agency – Wildlife Services					
		FY 17	FY 18	FY 19	FY 20	FY 21
	New Confidentiality Agreements	5	9	8	10	4
	New Material Transfer Agreements	7	12	9	12	19
	New Material Transfer Research Agreements	6	15	13	7	8
	Peer-Reviewed Scientific Publications	108	175	122	105	132
	Nonindexed Publications	20	23	11	18	18

2.5.5. Success Stories Demonstrating Downstream Outcomes from Technology Transfer Activities

National Wildlife Research Center, Publication of the Year Award

The NWRC averages 125 publications annually. Each publication is critical to advancing the understanding of science, methods development, and management to resolve human-wildlife conflicts. Each year, NWRC recognizes one publication having the greatest impact to our mission. A panel of NWRC scientists review the previous year's publications and selects a winner(s) for the NWRC Publication Award.

This year, the NWRC selected Dr. Kurt Vercauteren and fellow editors for the Publication of the Year Award for exceptional work on the book "*Invasive Wild Pigs in North America: Ecology, Impacts, and Management.*" VerCauteren, K.C., J.C. Beasley, S.S. Ditchkoff, J.J. Mayer, G.J. Roloff, and B.K. Strickland, editors. 2020. CRC Press, Boca Raton, FL. 479 pp. The Wildlife Society's 2020 Wildlife Publication of the Year also selected this book in the Edited Book Category.

This publication arose from a multidisciplinary collaboration between the NWRC, University of Georgia, Auburn University, Michigan State University, and Mississippi State University. Kurt Vercauteren and his co-editors assimilate and organize information on wild pigs (feral swine), the most destructive introduced vertebrate species in the United States. Many NWRC scientists directly contributed to the book's chapters. The book addresses all aspects of wild pig biology, ecology, damage, and management into a single comprehensive volume from which managers, researchers, policy makers, and other stakeholders can build upon. The impact of this book on WS operations, stakeholders, the public, and future research endeavors is substantial.

Participation in the Federal Laboratory Consortium

John Eisemann (Regulatory Support Services Unit Manager at the NWRC) is the Technology Transfer Coordinator for Wildlife Services. Eisemann coordinates all technology transfer activities, outreach, and trainings for Wildlife Services employees. In 2021, he was elected as Vice-Chair of the national Federal Laboratory Consortium (FLC), which he holds until the end of FY 23. He previously served 3 years as the Coordinator and Deputy Coordinator of the FLC Mid-Continent Region. As noted in the FLC 2020 Annual Report to the President and Congress, the FLC is the formally chartered, nationwide network of more than 300 Federal laboratories, agencies, and research centers that fosters commercialization best practice strategies and opportunities for accelerating Federal technologies from out of the labs into the marketplace.

 While with the FLC, Eisemann helped FLC leadership draft a new 5-year strategic plan which organized the structure and function of the FLC Executive Board and committees around three pillars of technology transfer: Promote, Educate and Facilitate. He helped draft the FLC and committee charters

and lead an evaluation of how FLC regional programs deliver technology transfer programming. Through Eisemann's elected positions and service to the FLC, Wildlife Services and the National Wildlife Research Center gained exposure to departments with developed R&D programs and introduced new networks for future technology development activities. In 2021, Eisemann helped organize an FLC regional meeting focusing on drone-mounted thermal and visual sensors in structural inspection, agriculture, and conservation applications.

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) 2021, ARS employed approximately 1,970 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 15 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. 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 created an Innovation Fund, from licensing revenue, to provide 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 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. The ARP Network communicates through LinkedIn. LinkedIn posts include 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 are 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 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 2021, there were 164 active CRADAs, 31 of which were newly executed. The 31 new CRADAs contributed $1,860,629 directly to ARS research projects, and approximately 40 percent of them are with small businesses. There were 333 active Material Transfer Research Agreements (MTRAs), 97 of which were newly executed. The 97 new MTRAs contributed $1,100,337 directly to ARS research projects (see Table 1 in Section 3.5 and Figures 1 and 2 in Section 3.9).

- In FY 2021, 172 new invention disclosures were received; 74 patent applications were filed; and 36 utility patents, 3 plant patents, and 1 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 2021, 51 new licenses were executed (69 percent with small businesses and 22 percent with universities). The total number of active licenses has steadily increased over the last 5 years from

419 to 613. Fifty-four percent of the income-bearing licenses were granted exclusively. The total income from all active licenses was more than $3.11 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 5 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 USDA's Animal and Plant Health Inspection Service (APHIS) and the Forest Service.

- OTT worked with the National Institute of Food and Agriculture's Small Business Innovation Research Program (NIFA–SBIR) to design strategies to enhance ARS technology transfer and economic development. OTT provided NIFA–SBIR informational slides that they added to their slide deck for presentations to small business audiences. NIFA-SBIR referred pre-vetted, small businesses to OTT for matchmaking with ARS researchers.

- Provided webinars on creating partnerships with ARS for the USDA's Office of Partnerships and Public Engagement (OPPE) and Farm Production and Conservation Business Center (FPAC); the Arkansas Small Business and Tech Development Center; Kansas Small Business Development Center; and the Washburn University BRITE Center.

- The COVID-19 pandemic prevented in-person training, which required OTT to develop a virtual form of the training. The virtual training was posted on-line through the ARS intranet (Axon).

- OTT, through the USDA Media and Broadcast Center, created a video explaining technology transfer and highlighting ARS technology transfer successes to replace static technology transfer display cases (https://www.youtube.com/watch?v=tpmBnQfq_BM).

- OTT worked with FLC on creating LabTech in Flight as a second module in the series LabTech in Your Life. The LabTech in Your Life series is a virtual environment where visitors can explore familiar settings and discover successfully commercialized Federal technologies that are now commonly used (https://federallabs.org/successes/labtech-in-your-life).

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

- OTT received 69 Innovation Fund applications, of which 23 were funded for a total of $556,135.

- In FY 2021, the ARP Network membership grew to 558. They were 20 LinkedIn posts to the ARP Network.

- 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.

3.5. Metric Tables

TABLE 1. Collaborative relationships for research and development					
	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total number of active CRADAS	249	189	193	147	164
Active CRADAs with small businesses	62	73	120	64	24
Total number of newly executed CRADAS	57	51	56	28	31
Newly executed CRADAs with small businesses	17	31	38	19	12
Total funds to be received	$2,804,160	$3,121,739	$3,280,189	$1,242,717	$1,860,629
Total number of active MTRAs[2]	432	354	292	323	333
Active MTRAs with small businesses	ND	ND	ND	ND	ND
Total number of newly executed MTRAs	101	118	100	106	97
Newly executed MTRAs with small businesses	ND	ND	ND	ND	ND
Total funds to be received	$743,603	$2,267,8864	$637,636	$1,575.241	$1,100,337
Total number of active other agreements[3]	4,108	3,215	1,888	1,987	2,443
Newly executed other agreements	876	621	951	1,210	995
Number of newly executed MTAs	664	645	614	423	472
Newly executed outgoing MTAs	445	476	398	266	335
Total number of publications[4]					
Peer-reviewed scientific journal	4,467	4,138	3,816	3,933	3,935
Trade journal	66	68	48	30	104

ND, data not available.
[1] Material Transfer CRADAs.
[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 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total new invention disclosures	169	306	228	188	172
University co-owned	27	29	39	24	19
Not university co-owned	21	16	18	13	9
USDA solely owned	121	261	171	47	40
Scientific discipline:					
Biological materials	8	141	86	46	74
Life science	72	55	47	35	29
Chemical	43	32	42	31	25
Mechanical & measurement	28	20	13	16	11
Plant patents[1]	5	6	2	4	0
Plant variety protection[1]	13	11	4	4	7
Plant breeder's rights[1]	0	0	1	0	0
Plant public release	44	41	33	52	26
Based upon CRADA research	22	23	14	11	8
Total U.S. patent applications filed[2]	109	108	85	76	74
University co-owned	21	31	17	20	19
Not university co-owned	23	25	17	20	17
USDA solely owned	65	52	51	31	38
Scientific discipline:					
Life science	45	53	29	22	22
Chemical	38	30	34	40	38
Mechanical & measurement	7	14	12	8	9
Plant patents	11	3	4	1	0
Plant variety protection	8	8	6	5	5
Total U.S. patents issued[2]	68	61	65	50	40
University co-owned	22	19	16	12	8
Not university co-owned	19	11	21	9	11
USDA solely owned	27	31	28	22	21
Scientific discipline:					
Life science	37	29	33	17	21
Chemical	13	15	17	17	10
Mechanical & measurement	6	12	4	6	5
Plant patents	6	2	8	3	3
Plant variety protection	6	3	3	7	1
Foreign patenting					
Total foreign patent applications filed	ND	ND	ND	60	14
Total PCT Applications Filed	ND	ND	ND	16	19
Total foreign patents issued	ND	ND	ND	3	3

ND, data not available.
[1] In the United States, plants may be protected in 1 of 2 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.
[2] Includes U.S. patent applications, divisional applications, continuation-in-part applications, provisional applications, and Plant Variety Protection.

TABLE 3. Profile of active licenses					
	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total active licenses[1]	426	460	497	565	613
Executed to small businesses[2]	155	161	180	236	270
Executed to universities	186	199	201	208	218
Amended in FY	4	8	4	4	6
Invention licenses[4]	351	374	377	393	412
Executed to small businesses	114	113	114	121	127
Executed to start-up businesses	6	6	6	6	6
Executed to universities	176	189	188	191	201
Other IP Licenses[5]	75	86	120	172	201
Executed to small business	41	48	66	115	143
Executed to startup businesses	0	0	0	0	0
Executed to universities	10	10	13	17	17
Total newly executed licenses	38	40	51	93	51
Executed to small businesses	19	12	25	74	35
Executed to startup businesses	0	0	0	0	0
Executed to universities	9	12	10	7	11
Invention licenses	29	27	17	30	22
Executed to small businesses	13	3	7	15	7
Executed to startup businesses	0	0	0	0	0
Executed to universities	8	12	7	3	11
Other IP Licenses	9	13	34	63	29
Executed to small businesses	6	9	18	59	28
Executed to startup businesses	0	0	0	0	0
Executed to universities	1	0	3	4	0
Total income-bearing licenses	425	459	496	564	612
Exclusive	293	312	312	316	329
Partially exclusive	6	7	7	7	7
Non-exclusive	126	140	177	241	276
Invention licenses[6]	350	373	376	392	411
Exclusive	283	302	299	300	313
Partially exclusive	6	7	7	7	7
Nonexclusive	61	64	70	85	91
Other IP licenses[7]	75	86	120	172	201

Exclusive	10	10	13	16	16
Partially exclusive	0	0	0	0	0
Nonexclusive	65	76	107	156	185
Total royalty-bearing licenses	129	134	125	109	99
Invention licenses	107	112	105	96	85
Other IP licenses	22	22	20	13	14
Elapsed Amount of Time for Granting Invention Licenses					
Average (months)	6.1	6.3	5.9	3.6	6.3
Median (months)	5.1	5.5	5.0	2.6	3.7
Minimum (months)	1.3	0.9	1.8	0.8	1.7
Maximum (months)	13.7	24.1	34.9	15.8	25.4
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 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 2017	FY 2018[1]	FY 2019	FY 2020	FY 2021
Total income all active licenses	$5,713,803	$3,799,170	$3,553,446	$3,243,196	$3,118,852
Invention licenses[2]	$5,377,909	$3,490,236	$3,272,205	$2,968,437	$2,877,587
Other IP licenses[3]	$325,566	$308,934	$281,241	$274,759	$241,265
Total Earned royalty income (ERI)	$3,503,866	$2,715,861	$3,171,355	$2,678,083	$2,399,480
Median ERI	$3,698	$3,056	$3,154	$4,221	$3,738
Minimum ERI	$15	$21	$ 0.75	$13	$0.02
Maximum ERI	$769,167	$265,844	$573,545	$279,915	$310,589
ERI from top 1% of licenses[4]	NP	NP	NP	NP	NP
ERI from top 5% of licenses	$1,639,557	$1,218,975	$1,579,185	$1,111,917	$1,068,082
ERI from top 20% of licenses	$2,933,342	$2,227,058	$2,655,368	$2,210,427	$2,107,125
ERI distributed					
Percentage Distributed to Inventors	25	25	25	25	25
Percentage Distributed to Lab/Agency	0	0	0	0	0
Innovation Fund[5]	$483,814	$618,000	$833,500	$898,144	$556,135

ND, data not available; NP, data not presented; ERI, earned royalty income.
[1] 2 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**

NP 107 Human Nutrition

Lean beef in a Mediterranean diet pattern reduces heart disease risk. Eating red meat has a reputation for being bad for the heart, but when consumed as part of a healthy diet, it might reduce heart disease risk factors such as bad cholesterol. ARS researchers in Beltsville, Maryland, and Pennsylvania State University colleagues conducted a dietary intervention study to determine how much lean beef can be included in a Mediterranean diet pattern to promote heart health. Volunteers consumed daily either 0.5, 2.5, or 5.5 ounces of lean beef as part of a healthy Mediterranean diet pattern or 2.5 ounces as part of a typical American diet. The researchers determined that a Mediterranean diet pattern that included lean beef consumption at all three levels reduced bad cholesterol and other risk factors for heart disease. While the traditional Mediterranean diet is low in lean beef, this study demonstrates how people can

incorporate lean beef into a healthy diet and benefit further from beef's other key nutrients. (NP107, Project No. 8040-51530-011-000D)

Adolescents with prediabetes or type 2 diabetes have impaired metabolic flexibility. Metabolic flexibility refers to the ability to utilize different nutrients (fats and sugars) and to transition between them while fasting and after a meal. Impaired metabolic flexibility can lead to metabolic disease, but it is not clear whether metabolic flexibility is impaired in obese youth. ARS-funded researchers in Houston, Texas, found that adolescents with prediabetes and type 2 diabetes have a defect in metabolic flexibility and are not able to change fuel use as easily as normal weight individuals or obese individuals who maintain normal sugar levels. The impairment results from severe insulin resistance that in turn impairs the appropriate use of available fuels. These results highlight the need for additional studies to investigate which changes in diet or physical activity could improve how the body utilizes these nutrients and help mitigate the risk of type 2 diabetes. (NP107, Project No. 3092-51000-065-000D)

Carbohydrates and fat intake influences the risk of metabolic diseases. It is not clear how the cellular process methylation controls genes associated with the risk of metabolic diseases such as obesity, type 2 diabetes, high blood pressure, hypertension, and abnormal lipids. ARS-funded researchers in Boston, Massachusetts, enrolled 3,954 Hispanic, Black, and White volunteers in a study to assess if carbohydrate and fat intakes influenced methylation and the risk of metabolic diseases. For each group and in a combination of the three groups, the analyses demonstrated strong associations of a specific methylation marker with metabolic characteristics such as body mass index, triglyceride, glucose, and hypertension. The results demonstrated carbohydrate intake induces a specific methylation site that reduces the risk of the metabolic diseases in the study, but that fat intake inhibits a specific methylation site and increases the risk of these metabolic diseases. These findings identify how

balancing carbohydrate and fat intake can affect metabolic disease risks that currently affect millions of Americans. (NP107, Project No. 8050-51000-107-000D)

Vitamin A (VA) supplementation improves immune function in Bangladeshi infants. Vitamin A (VA) protects against respiratory and intestinal infections, but the protective mechanism is not fully known. In animals, VA increases a protein that allows immune cells to migrate to the intestinal mucosal immune sites where they protect against pathogenic microorganisms. However, this has not been shown in humans. ARS researchers in Davis, California, working with International Centre for Diarrhoeal Disease Research colleagues in Bangladesh, conducted a trial of VA supplementation in 306 Bangladeshi newborns and found that VA increased expression of this protein by T regulatory (Treg) cells in early infancy. Treg cells play a central role in regulating immunity at mucosal surfaces. These results suggest that VA supplementation during infancy prompts an increased expression of this specific protein, which in turn reduces the risk of death from common childhood infections in populations at risk of VA deficiency. (NP107, Project No. 2032-51530-026-000D)

NP 108 Food Safety

Semicarbazide during poultry processing. To ensure food is safe from chemical contaminants, detection technologies should be accurate and reliable. Semicarbazide (SEM) is an indicator compound used by national and international organizations to infer the use of nitrofurazone, a banned antibiotic, in animal production. Recently, the detection of SEM by a significant importer of U.S. poultry resulted in an import ban for products from specific processing plants. The validity of using SEM as an indicator for nitrofurazone has been questioned in recent years. Strong evidence has emerged that sanitizers used in processing facilities to decontaminate meat may chemically create SEM from biological molecules in

the complete absence of nitrofurazone use. Studies conducted by ARS researchers in Athens, Georgia, support this unintentional production of SEM on poultry meat. An extensive survey of poultry processing plants indicated that the use of certain antiseptic chemicals, in combination with pH, can react with meat tissue to produce detectable levels of SEM. These data confirm that incidental production of the chemical can occur in processing facilities; therefore, SEM is not a reliable indicator of nitrofurazone, and alternative indicators of nitrofurazone use should be developed. This data has been transferred to food safety regulatory agencies, industry, and trade organizations to ensure and avoid inaccurate contamination reports, and to eliminate economic loss and potential trade issues. (NP108, Project No. 6040-42000-043-000D)

Deep learning approach for classifying contamination levels. Mercury (Hg) and arsenic (As) ions have been recognized as chemical threats to human health and can be present in foods in trace amounts. A critical issue recognized by the Food and Drug Administration and other organizations is the difficulty detecting low contamination levels in the parts per billion range. This remains challenging due to the small number of available data samples and significant intraclass variance. ARS researchers and colleagues at Purdue University's Center for Food Safety Engineering explored techniques for synthesizing realistic colorimetric images and proposed a Convolutional Neural Network (CNN) classifier. The system was trained and evaluated on a dataset of 126 images captured with a cell phone camera representing 5 contamination levels. The system accurately classified 88.1 percent of the contaminated images and classified contamination levels with a precision level of 91.9 percent. Using this system would allow regulators, processers, and consumers to use cell phone cameras to capture images that can estimate heavy metal contamination levels and advance the protection of the food supply. (NP108, Project No. 8072-42000-077-000D)

Shelf life and season are drivers of *Escherichia coli* O157:H7 survival on cut lettuce. *Escherichia coli* O157:H7 infections from contaminated lettuce continue to impact public health and the U.S. lettuce industry, which is valued annually at nearly $2 billion. Outbreaks linked to products grown in California occur predominantly from fall-harvested lettuce, and the reason for this seasonality is unknown. ARS researchers in Albany, California, and partners at the Food and Drug Administration Center for Food Safety and Nutrition identified the fall season and lettuce cultivars with poor shelf life as the main drivers of *E. coli* O157:H7 survival and microbiome structure. These results open new fields for inquiry into the seasonal aspects of the physiology of fresh-cut lettuce and its microbiome that may prevent the seasonal occurrence of *E. coli* O157:H7 infections. Likewise, the identification of shelf life as an important lettuce trait in *E. coli* O157:H7 survival suggests that genetic breeding for improved lettuce shelf life could be an integral part of a successful strategy to enhance produce safety. (NP108, Project No. 2030-42000-050-000D)

Enhancing foodborne pathogen sampling at processing facilities. Establishments producing raw ground beef products develop sampling protocols that are used to determine if microorganism levels in their products are below predetermined baseline levels and that control processes adequately protect against contamination. Sampling methods are critical since improper microbiological sampling can incorrectly indicate that processing methods are effective. ARS researchers in Clay Center, Nebraska, developed new continuous (CSD) and manual (MSD) meat sampling devices for raw beef trim, and developed and validated protocols now used in commercial processing that address common variations in sampling. Findings indicate that the various alternative applications of CSD- and MSD-based trim sampling for pathogen detection are equivalent or better than previous methods and provide additional benefits in reduced labor costs, other costs, and improved worker safety. (NP108, Project No. 3040-42000-019-000D)

NP 306 Product Quality and New Uses

Germ-fighting, durable, nano-enhanced cotton. Current methods to make fabrics with germ-fighting properties rely on surface coatings, but these surface coatings typically have poor durability and lose their functionality after only a few uses. ARS scientists in New Orleans, Louisiana, developed a new technology to produce permanent antimicrobial cotton products by synthesizing inexpensive copper oxide nanoparticles, which are powerful antimicrobial agents, within the cotton fiber. This process does not require the use of harsh chemicals. It is the first known development of a nano-enhanced cotton having long-lasting antimicrobial performance (50 laundering cycles) that is easily transferrable to large-scale manufacturing. It is anticipated that these active fabrics will have a market value reaching $1.1 billion by 2026. (NP306, Project No. 6054-41000-108-000D)

Green jet fuel from yeast now at commercial scale. U.S. airlines have committed to reducing carbon dioxide emissions by 50 percent in 2050, which has generated significant demand for renewable jet fuel that can be used to replace the 23 billion gallons of fossil fuel currently supplying the jet fuel market. ARS scientists in Peoria, Illinois, assembled a collection of yeasts that convert agriculture waste into bio-oil, which is then easily converted into biodiesel or renewable jet fuel. One of these yeasts (*Rhorosporidium toruloides*) was used in a pilot demonstration at a commercial development center to convert sugarcane bagasse into bio-oil. The yeast produced 18 grams of bio-oil/100 grams of agricultural waste, demonstrating that it is robust enough to produce bio-oil in a commercial, large-scale operation. This accomplishment supports President Biden's mandate to reduce fossil fuels and convert underutilized agricultural residues into value-added, green biofuels that support rural economies. (NP306, Project No. 5010-41000-189-000D)

New highly efficient apple harvesting robotic arm. Automated harvesting technology is urgently needed to address U.S. labor shortages and increasing labor costs facing the multibillion-dollar U.S. tree fruit industry. Although research into robotic harvesting has been reported in recent years, two technical challenges—picking fruit from clusters, and finding fruit obscured by leaves and branches—still need to be resolved. An ARS engineer in East Lansing, Michigan, and Michigan State University scientists developed a new robotic apple harvesting technology that couples an innovative concept of vacuum sucking and rotation with a simple and effective robot arm movement mechanism. When the new harvesting robotic arm was tested in 2020 during multiple commercial field trials, it effectively and skillfully picked fruit from clusters and from deep within the canopy where apples were obscured by leaves and branches. A patent application for this technology has been filed. (NP306, Project No. 5050-43640-003-000D)

A novel, water-conserving microgreen growing system. Feeding the increasing world's population with shrinking arable land and water resources requires novel alternatives to soil-based cultivation systems and creative solutions to minimize water usage. ARS scientists in Beltsville, Maryland, developed a biodegradable, hydrogel-based "artificial soil" that minimizes water use and labor. By improving water retention/delivery and root zone aeration, this new technology supports a full 14-day growth cycle for microgreens, which equals conventional production yields without the daily watering requirements. This current technology supports facilitating live plant shipping and user-friendly vegetable growth kits for health-conscious consumers and novice urban farmers. Early and enthusiastic feedback and adoption from urban farmers indicates potential widespread adoption by the urban farming industry. In addition, NASA scientists are investigating using this technology for producing food during space travel. (NP306, Project No. 8042-43440-006-000D)
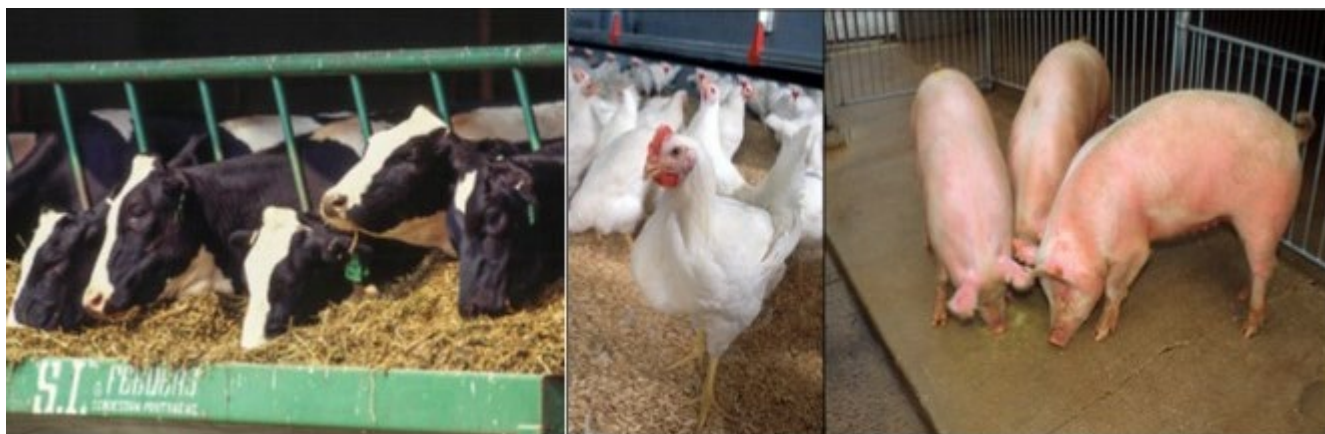
ANIMAL PRODUCTION AND PROTECTION

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

NP 101 Food Animal Production

Rapid eye temperature measurement to evaluate animal health. Rapid temperature measurement using forehead thermometers has become normal practice for humans, but current practices in cattle rely on obtaining rectal temperatures which is time consuming. ARS scientists in Lubbock, Texas, and university collaborators studied infrared ocular thermography, measuring the temperature of the eye, to detect fever in cattle. Results indicate that infrared ocular thermography can detect fever in cattle in less than 30 seconds and that eye temperature is highly correlated with rectal temperature. Adopting this rapid method for detecting fever in cattle allows high-throughput measurement in production facilities that will improve cattle management and sickness identification practices, improve cattle well-being and productivity, and reduce production costs. (NP101, Project No. 3096-32000-008-000D)

Farm Genotype-Tissue Expression (FarmGTEx) Consortium and the Cattle Gene Atlas.

Understanding the regulation of livestock gene expression underpins the study of biological mechanisms that contribute to economically important traits and animal improvement through selective breeding. FarmGTEx is an international collaboration focused on the development of a comprehensive atlas of tissue-specific gene expression and genetic regulation in farm animals. Co-led by ARS scientists in Beltsville, Maryland, and researchers at the University of Edinburgh, Scotland, and 20 other universities and institutes around the world, FarmGTEx built a Cattle Gene Atlas using approximately 12,000 publicly available RNA-sequence datasets that represented more than 100 tissues and cell types from more than 40 cattle breeds. The atlas describes the landscape of RNA expression in the genome and across tissues, and identifies variation in gene expression and protein isoform variants for 24 major tissues and 43 economically important traits in cattle. This data portal allows researchers to query gene expression, alternative splicing, and DNA regions associated with economically important traits in an easy, uniform way. FarmGTEx serves as the primary international reference source for cattle genomics, breeding, adaptive evolution, comparative genomics, and veterinary medicine. This research directly addresses the collective quest to enhance efficiency in cattle production and contributes to improvements in the environment, sustainable systems, and consumer expectations of beef and dairy products. (NP101, Project No. 8042-31000-001-000D)

A new method to screen the gastrointestinal microbiome of livestock. The microbiome is the combined genetic material of all microorganisms—such as bacteria, fungi, protozoa, and viruses—that live in a particular environment. ARS scientists in Madison, Wisconsin, and Beltsville, Maryland, led research conducted by an interdisciplinary team of international researchers from four countries and two private United States companies to develop new methods for microbiome screening to identify the organisms present. Using the latest high accuracy, long-read DNA sequencing technologies, microbial

strains could be resolved down to single nucleotide variants. More than 44 bacterial genomes were assembled into single, continuous chromosome genomes, which is the greatest number ever achieved in a single sequenced sample; more than 400 viral- and 250 plasmid-host associations were identified. These discoveries represent the highest resolution image of genomic DNA in a gastrointestinal sample, furthering the interpretation of microbiome sequencing discoveries and the future identification of "high-value" organisms influencing animal efficiency and health. (NP101, Project No. 5090-31000-026-000D & 8042-31000-001-000D)

Genome assembly of closely related microbes in metagenomic DNA samples. A metagenome is the recovery and sequencing of all genetic material in an environmental sample. Metagenomic assembly is hampered by the presence of multiple bacteria that are closely related in a genome sequence, but can represent different strains, species, or subspecies. Improper assembly reduces the accuracy of linking antibiotic resistance genes to a specific strain or species, and accuracy is essential when potential pathogenic microbes are present along with closely related nonpathogenic organisms. ARS researchers in Clay Center, Nebraska, and university collaborators developed a method to separately assemble genomes from mixed genomic material, even within the same species, while simultaneously providing links to antibiotic resistance genes that reside in the bacteria but that are not integrated into the bacterial chromosome. This new method offers great promise in clinical microbiology and livestock production sectors by enabling sequence-based tracking of strain-level genomes more efficiently and effectively than previous methods. This new method also improves the ability to determine if antibiotic resistance genes are associated with known human or animal pathogens; it also can reduce diagnostic costs and wait times. (NP101, Project No. 3040-31000-100-00D)

NP 103 Animal Health

Discovery of continuous cell line to detect African swine fever virus infectious field isolates.

African swine fever virus (ASFV) field isolates only replicate in primary cultures of swine white blood cells (macrophages), which are time consuming to prepare and require a herd of healthy donor pigs. These factors make swine macrophage cultures inaccessible for most diagnostic laboratories trying to identify infections in suspect field samples. ARS scientists in Greenport, New York, discovered that a cell line of monkey origin, Ma-104, was highly susceptible to infection with field isolates of ASFV. Results showed Ma-104 cells can be readily infected by all ASFV isolates tested. Furthermore, ARS researchers discovered the detection sensitivity was just below that of primary swine macrophage cultures and above the sensitivity of conventional real-time PCR methods. This discovery is of paramount importance for ASFV diagnostics as it will enable diagnostic laboratories worldwide to perform detection of ASFV infectious particles using a readily available cell line that is easy to grow. A patent covering the use of Ma-104 cells for ASFV diagnostic was filed by the ARS Office of Technology Transfer. (NP103, Project No. 8064-32000-061D)

A swine-origin H3N2 influenza virus closely related to human H3N2v demonstrated transmission from swine to ferrets. The transmission of influenza A viruses (IAV) from swine to humans occurs sporadically and is often associated with U.S. agricultural fairs. IAVs from swine that are detected in humans are called "variant" to differentiate from human seasonal IAV. During the 2016-2017 influenza season, 61 H3N2 variant (H3N2v) cases were reported. ARS scientists in Ames, Iowa, compared the genomes of human H3N2v viruses and swine H3N2 viruses collected at the same 2017 State Fair in Ohio, where ferrets were also directly infected with the H3N2 virus. In the study, pigs were infected with the virus and placed in an enclosure close to caged ferrets, which were chosen to test the spread of H3N2 because IAV transmission and infection in ferrets serves as model for human IAV transmission and infection. Results demonstrated that the swine H3N2 replicated in both pigs and ferrets exposed to

the respiratory aerosols of infected pigs, showing potential transmission from pigs to susceptible ferrets. These results are the first to show a transmission model from swine to ferrets without modification to the virus, and highlight the need to reduce swine IAV at animal exhibits. This study also demonstrates the importance of continued surveillance, research, and collaboration on swine and human IAV. (NP103, Project No. 32000-120-00D)

Culicoides **biting midges can transmit vesicular stomatitis virus during mating.** Biting midges are well-known agricultural pests and transmit vesicular stomatitis virus (VSV) to cattle, horses, and swine. VSV outbreaks occur every 3 to 8 years in the United States and result in significant economic losses due to reduced animal health, animal movement restrictions, and quarantines. In temperate regions, viruses can overwinter in the absence of infected animals through unknown mechanisms and reoccur the next year. To better understand whether the virus can be maintained in insect populations that initiate these multi-year outbreaks, ARS researchers in Manhattan, Kansas examined whether the virus could pass between male and female midges during mating. They showed that VSV-infected females could transmit the virus to uninfected naïve males, and infected males could transmit the 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 in *Culicoides* spp. 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 the understanding of arbovirus outbreaks. Furthermore, these results could lead to a more comprehensive understanding of potential virus persistence in nature between outbreaks, help explain the ability of some virus strains to survive through the winter and support multiyear outbreaks, and help explain transmission dynamics during viral outbreaks. (NP103, Project No. 3020-32000-013-00D)

Analysis of U.S. vulnerabilities to Japanese encephalitis virus. Japanese encephalitis virus (JEV) is a mosquito-transmitted virus that can infect multiple animal species and cause severe disease and death in humans. JEV is endemic in Asia and the Pacific region but is not currently present in the United States. However, JEV has demonstrated the ability to spread to new geographic regions, and previous studies determined the United States is at high risk for JEV introduction. ARS researchers in Manhattan, Kansas, collaborated with Kansas State University researchers to better understand the challenges and consequences associated with potential JEV introduction into the United States. Results highlighted several areas of vulnerability, including increases in wild animal populations that can transmit the disease, illegal animal importation and movement, the reduction in mosquito control in regions with highest risk, and changing patterns of viral strains. Identifying these gaps can help target animal and mosquito monitoring to detect an incursion of JEV more rapidly. This information will also be useful to direct future research, such as studies of the effectiveness of existing vaccines against different strains of JEV. Efforts such as these can reduce the potential consequences of a JEV incursion in the United States. (NP103, Project No. 3020-32000-014-00D)

New Johne's vaccine for cattle. Johne's disease, a serious disease of dairy cattle, is caused by Mycobacterium avium subsp paratuberculosis (MAP). ARS researchers in Ames, Iowa, conducted trials in dairy calves to test a new sub-unit Johne's disease vaccine containing a cocktail of recombinant proteins. In two trials, the highest dosages of the vaccine significantly reduced (MAP) colonization of intestinal tissues and resulted in the greatest reduction in infection. The vaccine also reduced fecal shedding of the pathogen, which is important for stopping on-farm transmission. Data has been used to support the patent application for this vaccine. These results will be of interest to producers, regulatory personnel, and researchers interested in intervention strategies for preventing Johne's disease in domestic livestock. (NP103, C5, PS5a, Project No. 5030-32000-221-000D)

NP 104 Veterinary, Medical and Urban Entomology

Attractant-impregnated adhesive stable fly tape. Stable flies are one of the most important arthropod pests of livestock. Stable flies reduce cattle weight gain and milk production, which leads to an annual economic loss of more than $2 billion to the U.S. cattle industry. ARS scientists in Lincoln, Nebraska, have identified attractant compounds that can be used with mass trapping techniques to reduce stable fly attacks on cattle. These attractants have been developed with adhesive technologies for stable fly control in feedlots to help cattle producers reduce stable fly infestation levels. A U.S. patent and an international patent application have been filed. A developed prototype product has been tested in the field, resulting in improved cattle protection against biting flies and an 80-percent reduction in cattle stress. (NP104, Project No. 3042-32000-011-000D)

Connecting genes to function in the stable fly. The stable fly is a blood-feeding pest of economic significance to U.S. cattle producers, reducing cattle productivity by an estimated $2 billion annually. Management of this pest is challenging, and novel methods of targeting stable flies are needed to enhance a producer's ability to suppress fly populations. ARS researchers in Kerrville, Texas, and Manhattan, Kansas, collaborated with scientists from 12 U.S. and 3 foreign universities to sequence and describe the genome of the stable fly. The team identified gene families involved in stable fly olfaction and vision, blood-feeding, reproduction, and metabolism of pesticide compounds. This important resource is being used to identify and target pathways that are critical to stable fly biology with the goal of developing unique strategies to reduce the burden of these flies on livestock production settings. (NP104, Project No. 3094-32000-041-000D)

Methodology to produce large numbers of irradiated *Aedes aegypti* males. *Aedes aegypti*, commonly known as the yellow fever mosquito, spreads dengue fever, chikungunya, Zika fever, Mayaro, and yellow fever viruses. ARS scientists in Gainesville, Florida, developed a novel methodology to produce tens of thousands of irradiated and sterilized male *Aedes aegypti* mosquitoes that can be used by mosquito control agencies for release in Sterile Insect Technique (SIT) programs. Male mosquitos do not feed on blood but mate with fertile females who subsequently lay infertile eggs. These standardized techniques were published and should facilitate the production of irradiated males required for mosquito SIT programs, greatly reducing the need for pesticide use and protecting people from these deadly viruses. (NP104, Project No. 6036-32000-052-000D)

U.S. populations of the invasive longhorned tick can transmit cattle *Theileria*. The invasive longhorned tick (*Haemaphysalis longicornis*) has spread rapidly in the Eastern United States since its initial report in 2017. In its native range, the longhorned tick is the vector of oriental thileriosis, which is an economically significant tick-borne disease of cattle caused by *Theileria orientalis*. Persistently infected cattle occur sporadically in the United States, but transmission and subsequent disease do not occur without a vector. ARS scientists in Pullman, Washington, and Beltsville, Maryland, infected cattle with an isolate of *T. orientalis* collected from a Virginia farm and transmitted it via tick-borne transmission to uninfected calves to demonstrate that this invasive tick can effectively transmit the disease. Transmission of *T. orientalis* by longhorned ticks represents a significant threat to the U.S. cattle population. The westward spread of longhorned ticks into areas where persistently infected cattle are present may lead to disease outbreaks and result in severe economic burdens on cattle producers. These results provide valuable information for U.S. cattle producers and reinforce the need for continued surveillance and enhanced control measures for this invasive tick. (NP104, Project No. 8042-32000-012-000D)

NP 106 Aquaculture

Improved fillet yield and body weight in rainbow trout. The proportion of edible meat (fillet yield) on a carcass is of major economic importance and breeding animals with superior fillet yield can improve production efficiency and profitability. Animals must be slaughtered to measure fillet yield directly, so it cannot be measured in breeding animals. However, developing genetic gains for fillet yield are possible using information, including genome information, from siblings of fish that are potential breeders. ARS researchers in Leetown, West Virginia, compared the accuracy of genetic merit predictions for fillet yield between the family-based selective breeding—which used information about family relationships—and genomic selection, which used information about family relationships and genomic information. The genomic selection model increased the accuracy of genetic merit predictions for fillet yield by 50 percent, indicating that the use of genomic selection can enhance genetic improvement for the fillet yield trait and further enhance the efficiency and sustainability of rainbow trout aquaculture. The industry is beginning to use this model. (NP106, Project 8082-31000-013-000D)

Recycled water use affects rainbow trout disease susceptibility and survival. Fish farmers often re-use water to conserve freshwater resources, but re-use is associated with reduced water quality that in turn is often blamed for disease outbreaks. More information is needed about risk levels associated with short- or long-term re-use water exposure, including how risks are associated with genetic traits and vaccine response. ARS researchers in Leetown, West Virginia, collaborated with researchers at Virginia Institute of Marine Science and Virginia Tech to study how two commercial breeds of rainbow trout vaccinated against infectious hematopoietic necrosis virus responded to exposure to re-used water. They found chronic exposure to water re-use increased the risk of death more than 46-fold and that these risks varied with the genetic makeup of the trout. This research demonstrated the importance of mitigating

effects of poor water quality and improving fish genetics to reduce disease loss. (NP106, Project No. 8082-32000-007-000D)

Sticky fish eggs thwarted by milk. Hybrid striped bass eggs become extremely sticky after they are fertilized. In a hatchery, this results in the eggs clumping together, which limits availability of oxygen and enables fungal infestations. Both problems can destroy an entire batch of eggs. Fish farmers typically use tannic acid treatments to prevent egg adhesion, but it is costly and, if left too long, will form a hard layer on the surface, which can prevent embryos from hatching. ARS researchers in Stuttgart, Arkansas, investigated 12 candidate compounds to prevent stickiness and found that 10 percent whole milk treatment was the most effective strategy. As a result, the largest commercial hybrid striped bass hatchery immediately began using milk for their 2020 production; in 2021, the hatchery exclusively used the milk to prevent clumping and successfully produced 80.9 million larvae using methods developed by ARS. (NP106, Project No. 6028-31630-009-000D)

Industry utilization of spawning aid. More than half of U.S. catfish aquaculture produces a hybrid between channel catfish females and blue catfish males. Hybrid production depends on induced ovulation in females, and producers traditionally utilized carp pituitary extract or a synthetic peptide based on a mammalian reproductive hormone to induce ovulation. ARS scientists in Stoneville, Mississippi, developed a synthetic peptide based on the chicken and catfish gonadotropin hormone releasing hormone (GnRH II), and helped producers test it on farms during the 2020 spawning season. The success of the new GnRH II on farms led to its use in 2021 by all eight producers who supply the U.S. catfish industry with hybrid catfish fingerlings, and six of the eight producers used GnRH II exclusively for hybrid production. (NP106, Project No. 6066-31000-016-000D)

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**

NP 211 Water Availability and Watershed Management

The ARS root-zone soil moisture technique improves drought early warning systems. The Soil Moisture Active Passive (SMAP) satellite is an effective method for monitoring soil moisture content at a coarse resolution (36-km grid). It is possible to refine this gridding to 9 km, but this is still too coarse for many agricultural applications. ARS scientists in Beltsville, Maryland, developed a new technique to produce 1-km soil moisture estimates, called the root-zone soil moisture technique. With these new high-resolution techniques, drought monitor systems can now be designed to optimally merge soil moisture information from multiple sources (including ground-based observations) and maximize the probability of early drought detection. The root-zone soil moisture technique enables USDA, Foreign Agricultural Service (FAS) to better monitor the impact of agricultural drought on global agricultural productivity. FAS formally integrated this SMAP-based technique into their Crop Explorer system and

their analysts are actively using it to improve their international commodity crop production forecasts. Early drought detection is critical to U.S. food security and for adaptive management. Global application of the ARS root-zone soil moisture technique is enhancing our global food security and national security. (NP 211, Project No. 8042-13610-029-000D)

ARS's improved spillway design is a key feature in rehabilitating dams. ARS researchers in Stillwater, Oklahoma, recently developed a new, lower cost and highly effective earthen dam spillway design. The USDA-Natural Resources Conservation Service (NRCS) adopted the design guidance and is integrating it into their National Engineering Handbook and expects its application will be used for about 1,200 dams across the United States. The total cost savings anticipated by NRCS for use of this technology is $600 million to $1.2 billion when compared to other rehabilitation options. This research is helping NRCS more efficiently renovate dams, preserving the estimated $2.3 billion in annual benefits provided to the U.S. public for flood control, rural and municipal water supplies, water for crop and livestock production, support for healthy ecosystems, and recreation and tourism. The U.S. Army Corps of Engineers anticipates integrating the new spillway designs in their revised "Hydraulic Design of Reservoir Outlet Works" technical manual (EM 1110-2-1602). These manuals are an industry standard among architectural and engineering consulting firms across the United States. (NP 211, Project No. 3072-13000-010-000D)

Long-term watershed research quantifies the benefits of conservation. Building and maintaining the ARS network of experimental watersheds and associated scientific investigations for more than half a century resulted in a range of accomplishments that directly benefit society. ARS researchers in Tucson, Arizona; Boise, Idaho; Tifton, Georgia; Beltsville, Maryland; Oxford, Mississippi; Columbia, Missouri; El Reno, Oklahoma; University Park, Pennsylvania; and collaborators at Kansas State

University identified and, in some instances quantified direct and indirect societal benefits. Development of conservation tillage practices has reduced erosion on U.S. cropland by 43 percent, contributing to healthier soils, and preventing 0.7 billion tons of soil from entering water bodies annually. Billions of dollars of infrastructure investment and methods to size bridges, culverts, and drainage infrastructure are guided by models developed from watershed observations and derived process knowledge. In some instances, ARS models were used outside the agricultural domain to guide the cleanup of soils at nuclear laboratory sites, savings billions of dollars. The ARS Experimental Watersheds were instrumental to the vision for and establishment of the Long-Term Agroecosystem Research (LTAR) Network. LTAR is expanding the mission of the ARS watershed network to include agricultural intensification without ecosystem degradation while enhancing rural prosperity. (NP 211, Project No. 5070-12130-006-000D)

Turfgrass filter strips remove nitrogen from runoff. Nitrate and ammonium, two forms of nitrogen found in chemical fertilizer, are very water soluble and are readily transported by field runoff to surrounding surface waters. Excess nitrogen in surface waters can lead to aquatic plant and algal blooms that block light and consume dissolved oxygen as they degrade, leading to areas of hypoxia and fish kills. ARS researchers in St. Paul, Minnesota, conducted studies to evaluate the ability of a fine fescue mixture vegetative filter strip to reduce quantities of nitrate nitrogen and ammonium nitrogen transported with surface water runoff. Measurement of nutrient concentrations in runoff at the entrance and exit of 50-ft vegetative filter strips revealed from 40- to 89-percent removal of nitrate nitrogen and from 77- to 98-percent removal of ammonium nitrogen. This research data can help land managers to make decisions that enhance environmental stewardship. (NP 211, Project No. 5062-12130-007-000D)

NP 212 Soil and Air

Improved methods for measuring soil carbon lower costs and increase accuracy. Two limitations to building credible soil carbon sequestration programs are the high cost and variability in soil carbon measurements. Part of the measurement variability is caused by small plant materials that cannot be removed by hand. ARS researchers in Pendleton, Oregon, developed a rapid way to remove large and small particulates using an electrostatically charged surface, which made the organic matter measurements more consistent. They also assessed a low-cost nondestructive spectroscopy technique to accurately detect small changes in soil carbon. To further increase the power of these approaches in soil carbon monitoring, they teamed with ARS researchers in Beltsville, Maryland; Lincoln, Nebraska; Mandan, North Dakota; Fort Collins, Colorado; and researchers at the Woodwell Climate Research Center and Rodale Institute. This team used soil samples from long-term research trials to show that this spectroscopy technique, when used in context of a USDA–NRCS laboratory spectral library, can be a reliable way to estimate soil carbon compared to traditional, more expensive lab methods. These improvements in measurement consistency and low-cost analytical techniques for soil carbon can be used by farmers seeking to improve soil management and benefit from ecosystem service markets. (NP 212, Project No. 2074-11120-004-000D)

Improving anerobic digestion processes to increase bioenergy production from organic waste streams. Anaerobic digestion and subsequent biogas production are essential to wastewater treatment and manure management. Increasing digestion efficiency is vital to reducing the cost of biogas production and reducing environmental costs of organic waste management. ARS scientists in Bowling Green, Kentucky, used sonification (sound supplied by submerged waterproofed speakers placed in the digester) to vibrate gas bubbles and speed up the breakdown of wastewater during digestion. Sonification produced 27 percent more biogas during the summer and an astonishing 74 times more biogas during the winter. In related research, ARS scientists in Florence, South Carolina, used a new

gas-permeable membrane technology to remove ammonia from wastes before digestion and found the biogas yield increased up to 28 percent and the percentages of methane in biogas were higher. This research provides novel technologies for improving anaerobic digestion for faster digester startup, reduced heating requirements during cool months, improved the quantity and quality of biogas produced, and improved recovery of ammonia nitrogen as a potential fertilizer product. (NP 212, Projects Nos. 5040-12630-006-000D and 6082-12630-001-000D)

Steam-flaked corn and high-quality hay lower greenhouse gas emissions from cattle. Methane, nitrous oxide, and carbon dioxide are greenhouse gases that contribute to climate change. When added together, the global warming effects of these three gases make up the carbon footprint. ARS scientists in Bushland, Texas; Woodward, Oklahoma; El Reno, Oklahoma; and university and non-government organization partners studied how dietary ingredients affect the carbon footprint of cattle. Greenhouse gas emissions were lower when cattle consumed a diet based on high quality hay. They found corn, a typical feedlot diet ingredient, is usually processed either by dry rolling or steam-flaking before being fed. Feeding the cattle steam flaked corn reduced the carbon footprint by 9 to 13 percent. Steam-flaked corn also reduced enteric methane emissions by 30 percent. These results show diet manipulation can be an effective method for reducing greenhouse gas emissions from cattle; high quality grass and steam-flaked corn are two feed management practices immediately available to producers. (NP 212, Project No. 3090-31630-005-000D)

Remote sensing helps optimize the ecosystem services provided by cover cropping practices. Cover crops are planted to reduce soil erosion, increase soil fertility, control weeds, increase soil carbon storage, and improve water quality by reducing nitrogen and phosphorus losses. Cost-sharing programs require cover crops to be planted in the fall and terminated in the spring within specified time windows.

Planting and termination dates are usually obtained through highly labor-intensive and expensive field surveys that require the participation of at least 20 percent of enrolled fields. In partnership with the Maryland Department of Agriculture and NASA, ARS scientists in Beltsville, Maryland, developed a decision support tool that uses satellite imagery and Google Earth Engine to calculate an index for measuring cover crop growth. Scientists also developed a new within-season termination (WIST) algorithm to map cover crop termination dates using remote sensing imagery. Remote sensing and mapping cover crop growth and termination dates improve the cover crop cost-sharing program by providing timely and cost-effective information to reduce staff workloads and optimize the use of cover crops with adaptive management approaches, thereby increasing ecosystem services by optimizing cover cropping practices. (NP 212, Project No. 8042-66000-001-000D)

NP 215 Grass, Forage, and Rangeland Agroecosystems

Targeted cattle grazing prevents megafires. Rangeland megafires (>100,000 acres) are becoming increasingly common in the Western United States, account for much of the $1–3 billion spent annually on wildfire suppression, and critically threaten human life, property, and natural resources. Targeted livestock grazing offers an efficient and effective means of curbing wildfire size and reducing damage by creating and maintaining fuel breaks strategically positioned between fire-prone landscapes, such as those dominated by highly flammable, invasive annual grasses like cheatgrass. In partnership with the Bureau of Land Management, ARS researchers in Boise, Idaho, used targeted cattle grazing to create fuel breaks at project sites in Idaho, Nevada, and Oregon. Intensive and carefully managed cattle grazing reduced vegetative fuel height, loading, and connectivity while avoiding adverse impacts to environment health within the fuel break areas. Targeted grazing fuel breaks have already reduced fire intensity and expansion in three wildfires at the Nevada project site, saving millions of dollars in property damages,

fire suppression, and subsequent landscape restoration. This allowed wildland firefighters to make more timely arrivals and apply better initial control options to contain the fires to smaller acreages. Targeted grazing provides a unique opportunity for agricultural producers, private landowners, and public land managers to strategically reduce fine fuels and wildfire size and severity with a tool that is already in place and at a scope needed for the annual grass-wildfire problem. (NP 215, Project No. 2052-13610-014-000D)

New data enables timely prediction of areas most at risk of wildfire in the Great Basin. Currently, western wildfire suppression costs $1-3 billion per year, and loss or damage to property and structures is extensive. During many years of plot-scale research, ARS scientists in Burns, Oregon, identified the large and often underestimated role that rangeland grass plays as fuel that influences wildfire ignition, spread, and intensity. ARS scientists collaborated with the University of Montana Rangeland Analysis Platform (RAP) team, who scaled the information up to create a landscape model that predicts the probability of large wildfires in the Great Basin region based on fuel accumulation (primarily perennial grass) and precipitation. RAP is a computer-derived estimate of vegetation cover and is based on Landsat satellite imagery dating back to the late 1980s. The fire model can account for 70 percent of variation in yearly acres burned in the Great Basin from 1988 to present. Model predictions are available on April 1 of each year, which allows enough time for fire managers to conduct fuel treatments and position suppression equipment before a fire begins. The new model was shared with the National Interagency Fire Center as the first fuel-driven, spatially explicit, and preemptive model accurate enough for broad management use in predicting wildfire occurrence in rangelands. (NP 215, Project No. 2070-21630-003-000D)

Making switchgrass a viable biomass crop for Midwest agroecosystems. Switchgrass is targeted as a feedstock for alternative fuels, such as for President Biden's initiative to develop more sustainable fuels for U.S. aviation. To become a sustainable biomass crop, switchgrass needs key traits, including perenniality, resilience to environmental stress like winter weather, and high biomass production, but there are no commercial switchgrass cultivars that combine all these traits. In the first evaluation of its kind, ARS researchers in Lincoln, Nebraska, and collaborators identified genetic mechanisms to improve switchgrass climate adaptation and yield. The genetic resources they developed are a critical milestone and reduce the time required to develop new high yielding bioenergy cultivars from 10 years to as little as 5 years. In related research, ARS scientists in Madison, Wisconsin, developed a new switchgrass cultivar that combines perenniality, persistence, and high biomass production in a northern-adapted population with 50- to 70-percent increased biomass production over traditional local cultivars and nearly 100-percent survival over three winters. The new cultivar is scheduled for public release in 2022 and dissemination to stakeholders for sustainable biomass production. (NP 215, Projects No. 5090-12210-001-000D and 3042-21000-034-000D)

Improved pasture mixes and annual forages increase dairy cow productivity. Milk production from cows grazing pasture is the fastest growing segment of organic agriculture. One challenge of organic production is that grazing dairy cows produce up to 32 percent less milk than nongrazing cows, mostly because they eat up to 30 percent less forage. ARS researchers in Logan, Utah, and Utah State University collaborators determined how much young dairy cattle eat and grow when grazing four different grasses alone or in mixtures with the legume birdsfoot trefoil. They found the mixtures of grass and birdsfoot trefoil increased the amount dairy heifers ate by 34 percent, improved growth by 25 percent, and increased heifer value around $166. In related research, ARS scientists in University Park, Pennsylvania, and University of New Hampshire collaborators evaluated five winter annual forages for

providing high-quality, lower cost pasture in early spring to meet grazing needs that traditional pasture forages cannot. Barley showed the most potential and fewest tradeoffs for supplementing spring pastures to maximize harvest yield and livestock nutrient value. These grazing tools are now being used by dairy farmers to increase cow forage intake and milk production. (NP 215, Projects No. 2080-21000-018-000D and 8070-21000-010-000D)

NP 216 Sustainable Agricultural Systems Research

Vegetable growers receive increased nitrogen credits for growing cover crops. Winter cover cropping is a best management practice for reducing nitrogen leaching into ground water in high-input vegetable systems, but only about 5 percent of irrigated land in the central coast region of California is cover cropped during the winter. To address the issue of ground water pollution from agriculture, a new regulation, known as Ag Order 4.0, was adopted in California. During the development of the regulation, an ARS researcher in Salinas, California, used long-term cover cropping data to justify increasing the nitrogen credit farmers would receive when they grow winter cover crops. This change improves the regulation to the benefit of both farmers and the environment and will incentivize cover cropping on 540,000 acres of irrigated land in this important vegetable production region of California. (NP 216, Project 2038-21620-014-000D)

Improved quantification of the environmental impact of U.S. dairy farms. ARS scientists in University Park, Pennsylvania, led a comprehensive life-cycle assessment (LCA) across six regions of the United States to provide regional and national estimates of dairy farm operations and their environmental impacts. Nationally, dairy farms were found to emit 1.5 percent of the estimated total of U.S. greenhouse gases. Blue water (defined as water sourced from ground and surface supplies) use

associated with dairy production was 3 percent of total U.S. blue water withdrawal. Fossil fuel energy use for dairy production was 0.3 percent of the U.S. total. While these aspects of the dairy industry's environmental footprint represent a relatively small portion of the national inventories, the LCA revealed there is a significant problem with reactive nitrogen loss, especially in the form of ammonia, where dairy farms may emit as much as 24 percent of the U.S. total. The LCA also revealed that the best opportunities for improving the dairy industry's environmental footprint are reducing these ammonia (and methane) emissions from manure storage sources, reducing enteric methane emission per animal, and reducing water use in feed production. This life-cycle analysis method can be used to tailor mitigation strategies that, for individual farms, are economical and do not result in an increase of one pollutant as a result of measures to reduce a different pollutant. (NP 216, Project No. 8070-66000-001-000D)

Conservation management restores health and function of degraded soils. There are several processes that can lead to soil degradation in agricultural and other land use, and ARS scientists are addressing these problems to restore soils to higher performance and quality. ARS scientists in Columbia, Missouri; Ames, Iowa; and Lubbock, Texas, (collaborating with multiple institutions) conducted a meta-analysis of soil health data from 456 agronomic and agroecological studies spanning 49 States where intensive cropland cultivation had led to soil degradation. The study found soil function can be slowly but eventually restored by implementing conservation practices such as reduced tillage, increased crop rotational diversity, and the inclusion of perennial crops in rotation. Soil degradation can also result from extreme weather events such as anomalous rainfall events (especially following drought), particularly in southwest U.S. arid rangelands. ARS scientists in Las Cruces, New Mexico, identified a new type of "grassy shrubland" ecosystem in restored rangelands that shows long-term (more than a decade) stability via high grass cover, soil carbon levels, soil health, soil water retention,

and low rates of wind erosion. Widespread soil degradation has also arisen from historical mining activities. ARS scientists in Corvallis, Oregon, and Florence, South Carolina, collaborated with scientists from the Environmental Protection Agency to develop biochar-based soil amendments that allow plants to thrive in these extreme environments. The amendments were deployed at the Formosa Mine in southern Oregon, where plants are now growing for the first time in four decades. Landowners and managers of public lands can implement these restorative management practices to regenerate degraded land. (NP 216, Project Nos. 5070-12610-005-000D, 3050-11210-009-000D, and 2072-12620-001-000D)

Advances in precision agriculture improve sustainability of wheat, corn, and canola cropping systems. ARS scientists are developing powerful mapping and imaging tools to fight weeds, improve planting outcomes, and fight diseases in crops. ARS researchers in Pendleton, Oregon, and Oregon State University researchers developed a way to map weeds in real time during harvest operations. The high-resolution weed maps were used to help explain variation in crop yield within the field and enable direct spot spraying of weeds after harvest before they re-infest the next crop. ARS researchers in Columbia, Missouri, and University of Missouri researchers developed a method for using aerial drone images to monitor corn emergence within the first week after planting; this method can be automated to help farmers scout fields for sections that need replanting. ARS scientists in Pendleton, Oregon, developed a procedure for monitoring the timing of canola flowering from satellite- or aircraft-based images that can be integrated with meteorological data to predict canola yield and disease risk. These newly developed remote sensing techniques are helping growers improve productivity and sustainability across a wide variety of national cropping systems. (NP 216, Project Nos. 2074-12210-001-000D and 5070-12610-005-000D)

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**

NP 301 Plant Genetic Resources, Genomics and Genetic Improvement

'Yorizane', a new self-fertile almond cultivar. Eighty percent of the world's almonds are grown in California, and the majority of the 1.5 million acres are planted with cultivars that require bees to transfer pollen between different trees to produce nuts. Self-fertile varieties require fewer pollinators in the orchard because the pollen moves only a short distance within the flower or within the tree to produce nuts. The California almond industry wants new self-fertile cultivars to reduce the need for honeybees and pollinators. ARS researchers in Parlier, California, developed the new self-fertile 'Yorizane' cultivar, which yielded well in regional trials throughout the San Joaquin Valley for five commercial harvests. 'Yorizane' nuts have been rated highly by the almond industry in marketing potential and kernel appearance and it has great potential for adoption by almond growers. (NP 301, Project No. 2034-21220-007-000D)

Molecular marker developed to select for resistance to low falling numbers in wheat. The falling number test is a measure of wheat grain quality. When wheat grain undergoes preharvest sprouting or germination before harvest, the grain deteriorates and low grain-falling numbers occur, leading to major losses to growers. ARS researchers in Pullman, Washington, and collaborators at Washington State University and the John Innes Centre identified a new mutant allele in wheat that has a specific single nucleotide change improving resistance to low falling numbers. Findings about this perfect DNA marker were published in Theoretical and Applied Genetics, and it is being adopted by wheat breeders to select for increased preharvest sprouting tolerance to avoid producer losses from low falling number test results. (NP 301, Project No. 2090-21000-033-00D)

New and improved potato variety released. The U.S. potato industry, valued at $4 billion annually, needs improved potato varieties. ARS researchers in Aberdeen, Idaho, and university colleagues in Idaho, Washington, and Oregon recently released 'Rainier Russet', a new potato variety that produces high marketable yields in both early- and full-season harvests, enabling its production in a greater diversity of growing regions. 'Rainier Russet' has cold-induced sweetening resistance and uniform fry color, which enables longer-term storage before they are used to make french fries. This is an improvement over other industry standard varieties, where converting starch to sugar results in a darker processed product. 'Rainier Russet' is also notable for long tuber dormancy, which promotes the retention of tuber quality in storage with reduced sprouting. 'Rainier Russet' has an attractive tuber that also makes it suitable for use for fresh consumption, as well as for processing. (NP 301, Project No. 2050-21000-035-000D)

Novel disease resistance in barley. Fungal pathogens are among the greatest threats to cereal grain production worldwide. ARS scientists in Ames, Iowa, applied genomic methods to identify a novel

variant of SGT1, a protein vital for all life, in barley. SGT1 mutations are usually lethal because they can interfere with the fundamental role this protein plays in survival. However, the novel SGT1 variant found by ARS researchers contains a unique mutation that helps stabilize other disease resistance proteins and increases overall robustness without triggering other potentially lethal changes. These findings demonstrate for the first time that this unique modification in the SGT1 protein can support disease resistance traits and can be used to facilitate greater disease resistance in crops. (NP301, Project No. 5030-21000-067-000D)

Gene level modeling improves predicting field performance. Maize has 37,000 genes that interact together as the plant grows and responds to the environment. One of the key goals of breeding is predicting these interactions from just the information included in DNA. ARS researchers in Ithaca, New York, and collaborators used novel statistical approaches to study more than 70 million measurements of how much RNA each of these genes produce under various conditions. Their results have substantially improved predictions of how thousands of varieties of maize will produce more than two dozen traits. Importantly, this approach could be applied for many other crops by enlisting the powerful genomic tools available. Long term, this will enable the application of advanced genomic models to all crops. (NP 301, Project No. 8062-21000-043-000D)

New peanut cultivars with disease resistance. Late leaf spot (LLS) is one of the costliest diseases of U.S.-grown peanuts. ARS scientists in Tifton, Georgia, created peanut breeding line IAC 322, which contains three chromosome segments from a wild species that provide a very high level of resistance to LLS. Two lines with very high levels of resistance to LLS were selected from this population, evaluated for other agronomic characters, and released with corresponding genetic markers as a technology package for determining the presence or absence of the introduced chromosome segments. These results

will allow breeders to use marker-assisted selection to develop peanut varieties with resistance to LLS more effectively and efficiently, thus reducing management costs of fungicide sprays and increasing sustainability and profitability. (NP 301, Project No. 6048-21000-029-000D)

Discovery of 33 toxin-producing, plant pathogenic fungi. During the past three decades, epidemics of the fungal disease Fusarium head blight (FHB) have caused economically devastating damage to wheat and barley in the United States and elsewhere around the world. FHB significantly reduces seed quality and yields and contaminates grain with toxins that pose a serious global threat to agricultural biosecurity, food safety, and human health. ARS researchers in Peoria, Illinois, characterized the genetic diversity of a global collection of 171 Fusarium strains either known or predicted to produce toxins. The 171 strains comprised 74 different species, including 33 that are new to science, and the species were distributed among 6 species groups that corresponded to the type of toxins they produce. The researchers found that species within only two of the six groups could cause FHB of wheat and contaminate grain with toxins. These data further suggest that the type of toxin produced contributes to the ability of these plant pathogens to cause disease. These findings will be of interest to plant disease specialists and quarantine officials who are focused on minimizing the threat these toxigenic molds pose to U.S. and world agriculture. Moreover, knowledge gained from this research should assist plant breeders in developing cultivars with broad-based resistance to FHB. (NP 301, Project No. 5010-22410-021-00D)

Pan-genomic resources provided by the Maize Genetics and Genomics Database (MaizeGDB). Crop research increasingly relies on knowledge of a pan-genome, which is a complete set of genes found across a species. Understanding pan-genomes is especially valuable in plants with high genomic diversity, such as maize, that can be exploited for crop improvement. ARS researchers in Ames, Iowa, introduced a pan-genomic approach to hosting a genome sequence database, leveraging the numerous

diverse maize genome sequences available and their associated datasets to efficiently connect plant genomes with traits of interest and their inheritance and control. During the past several years, MaizeGDB has transitioned from hosting a single reference genome sequence to hosting data and tools integrated across 44 diverse maize genome assemblies. Recent improvements at MaizeGDB include an improved method for gene annotation, a tool to visualize structural variation across genomes, and methods to connect functional annotations across genomes. This pan-genome approach provides a template for other crop databases. It is also a resource to facilitate improved crop performance by helping researchers understand the relationship between the genes in a plant and the traits observed in crop fields. (NP 301, Project No. 5030-21000-068-000D)

A new type of wheat gene governing disease resistance. Septoria tritici blotch (STB) is a major fungal disease of wheat worldwide. ARS researchers in Fargo, North Dakota, and collaborators in France and The Netherlands discovered a gene from wheat that provides resistance to STB. The gene, Stb16, belongs to a class of genes that has not previously been associated with disease resistance in plants; it makes wheat resistant to many strains of the STB fungus and will enable plant breeders to develop new STB resistant varieties. This discovery was reported in Nature Communications. (NP 301, Project No. 3060-21000-038-000D)

Tools for genome editing in alfalfa. Alfalfa is the third most widely grown crop in the United States, but breeding for increasing herbage yield, quality, and stand persistence has been slow. Using genome editing to modify the alfalfa genome can accelerate development of more productive and environmentally resilient cultivars, but it is complicated by the multiple copies of each gene in alfalfa. ARS scientists in St. Paul, Minnesota, developed novel genome editing reagents that more efficiently edited a regulatory gene in alfalfa. Mutations were identified for the first time through targeted

sequencing of the mutated areas, significantly accelerating identification of mutant plants and reducing costs of identifying mutant plants by tens of thousands of dollars. DNA sequences were identified that will facilitate the tracking of mutations when cross pollinated to other alfalfa backgrounds. These tools will accelerate development of improved alfalfa cultivars for bioremediation, animal nutrition, and nutrient uptake. (NP 301, Project No. 5062-21000-033-000D)

Using machine learning to predict corn yield from genetic, environment, management, and historical data. Predicting how new cultivars will perform in new environments is a longstanding challenge in agriculture and has the potential to increase breeding effectiveness and producer profitability. ARS researchers in Columbia, Missouri, and Ithaca, New York, developed computational methods (known as machine learning, deep learning, or artificial intelligence) that increase prediction accuracy by 7 percentage points compared to current state-of-the-art methods. These results, published in Theoretical and Applied Genetics, will potentially enable breeders to accelerate the development of breeding lines and cultivars for specific environments. (NP301, Project No. 5070-21000-041-000D)

Release of commercial sugarcane variety 'HoCP 14-885'. ARS scientists in Houma, Louisiana, in collaboration with the American Sugar Cane League of the U.S.A., Inc. and Louisiana State University Agricultural Center, developed and released a new sugarcane variety in 2021. The new variety, 'HoCP 14-885,' is resistant to sugarcane smut caused by *Sporisorium scitamineum*, mosaic caused by sorghum mosaic virus (SrMV), and brown rust caused by *Puccinia melanocephala*. It has moderate cold tolerance, early maturity, and high sugar yields through multiple harvests. Early maturity is important in Louisiana because the harvest season can be reduced due to late season freezing temperatures. The release of this cultivar offers growers a well-adapted variety that exceeds the sugar yields of the current leading variety across the harvest cycle. Due to its yield stability and resistance to major diseases,

'HoCP 14-885' can increase industry profits and expand the genetic variability of sugarcane within the growing region. Several growers have requested 'HoCP 14-885' plants. (NP 301, Project No. 6052-21000-016-000D)

Microwave irradiation for eliminating bacterial leaf scorch from pecan graftwood. Pecan is an important crop for large-scale and small-scale producers in the Southeast, Southwest, and South-Central United States, and in 2018 had a national farmgate value of $425 million. Pecan bacterial leaf scorch disease caused by *Xylella fastidiosa* is widespread in U.S. pecan production areas and can be transmitted from pecan scions to rootstocks via grafting. ARS researchers in College Station, Texas, and university colleagues developed a thermal treatment that employs microwave irradiation and microwave absorbers to kill or deactivate *X. fastidiosa* in pecan scions. These techniques provide researchers and industry personnel with additional options for treating infected pecan graftwood to reduce the spread of the leaf scorch disease. Microwave irradiation is faster and requires less energy than current hot-water methods for treating *Xylella*-infected pecan graftwood. This innovation also furnishes a scientific foundation for developing novel treatments that incorporate microwave irradiation and microwave absorbers to control vascular pathogens of other crop species. (NP 301, Project No. 3091-21000-042-00D)

Field-based high-throughput plant evaluation for chlorophyll fluorescence. Photosynthetic efficiency is important for improving crop yields in hot and dry environments and is very challenging to measure in the field. The LEMNA-TEC Field "Scanalyzer" is the largest field robot in the world. It is operated by the University of Arizona in Maricopa, Arizona, and is equipped with a chlorophyll fluorescence imaging system that needed validation for effective application to large-scale plant phenotyping. ARS researchers in Maricopa and collaborators from the University of Arizona and the Donald Danforth Plant Science Center developed the software and data processing pipeline to extract

measurements needed to determine photosynthetic efficiency, thus validating the system for field phenotyping. This work has established a standard that enabled field trials to capture the temporal dynamics of chlorophyll fluorescence for plants grown in a hot and dry environment. To date, it has been applied to research on lettuce, sorghum, and sunflower. This system provides a valuable new tool for plant researchers to develop novel germplasm adaptable to sustainable crop production in hot and dry environments. (NP 301, Project No. 2020-21000-013-000D)

New reference genomes of pathogen that causes aflatoxin production in corn. Available genome sequences of *Aspergillus flavus*, one of the main pathogens that causes aflatoxin, have been invaluable for characterizing genes involved in aflatoxin production. However, an understanding of *A. flavus* diversity has been hindered by the lack of suitable and diverse references. ARS researchers in Tifton, Georgia, led a team of collaborators in constructing two reference genome sequences for two different *A. flavus* isolates. These isolates were chosen based on their variation in aflatoxin production and responses to reactive compounds associated with drought stress that increase aflatoxin production. These genome analyses revealed several key genes, including a novel gene that may be involved in oxidative stress tolerance and aflatoxin production. This information was used to sequence 264 genomes of different *Aspergillus* isolates from field soils in Georgia and corn plants in Mississippi. These data will contribute to additional comparative studies to identify novel aflatoxin regulators, shedding light on the origin and evolution of these new genes, and providing valuable tools for aflatoxin and crop research. (NP 301, Project No. 6048-21000-028-000D)

NP 303 Plant Diseases

Managing tomato brown rugose fruit virus. Tomato brown rugose fruit virus (ToBRFV), an emerging and economically important plant virus, has caused serious disease outbreaks on greenhouse tomatoes around the world in recent years. This seed-borne and mechanically transmitted virus poses a serious threat to the $2.5 billion tomato and pepper industries in the United States. Recently, ARS researchers in Charleston, South Carolina, reported an outbreak of ToBRFV on tomatoes for the first time in the United States. Based on this report, USDA-APHIS issued a Federal order to inspect all imported tomatoes and peppers for ToBRFV infection to prevent potential devastation to the U.S. tomato industry. Also, the researchers conducted molecular and biological characterizations of ToBRFV isolates in the United States and developed a highly sensitive real-time PCR detection system for the virus that can also be used for seed health testing. Additionally, several disinfectants that kill the virus and prevent the disease from spreading have been identified and recommended to growers. Furthermore, the researchers screened available tomato germplasm and identified new sources of resistance that are being used in breeding to develop plants that are resistant to the virus. These research findings will provide fundamental knowledge and practical solutions to prevent and protect tomato and pepper crops in the United States and around the world from potential devastation by this emerging and economically important plant pathogen. (NP 303, Project No. 6080-22000-028-00D)

New viruses passed on by whiteflies threaten cucurbit crops in California's Central Valley. In the U.S. Southwestern low desert, two yellowing viruses are known to impact summer and fall cucurbit production. These two viruses had not been previously known to infect plants in the Central Valley of California, where more than half of U.S. cantaloupe production occurs. During the fall of 2020, ARS scientists in Salinas, California, identified both viruses from melon plants in Fresno County, California, using a virus detection system developed by the ARS laboratory. These first reports were published in the journal Plant Disease. The viruses have the potential to cause severe losses, and it is important for

the cucurbit industry that continued monitoring occur to determine prevalence and to develop strategies to reduce the impact of the virus. (NP 303, Project No. 2038-22000-018-00D)

New sources of resistance to root-knot nematodes in peanut. The peanut root-knot nematode (PRKN) is a microscopic worm that inhabits the soil. It infects peanut roots and pods and can cause substantial yield losses to peanut growers. Currently, there is only one available source of genetic resistance to this nematode in peanut, and additional sources are needed to improve the durability of resistance. ARS scientists in Tifton, Georgia, and University of Georgia collaborators used a technique known as marker-assisted selection to transfer two new genes that showed resistance to PRKN from a wild peanut species into cultivated peanut. High levels of resistance to PRKN were confirmed in these advanced peanut breeding lines. These new sources of PRKN resistance can be used by peanut breeders to create durable resistance when combined with the previous resistance source. This germplasm is available through the Germplasm Resources Information Network (GRIN). (NP 303, Project No. 6048-21220-016-00D)

A new microscopic worm that attacks turf grass in Oregon. Cyst nematodes are microscopic worms that cause billions of dollars of crop losses each year in the United States. Some cyst nematodes infect turf grass and ruin golf courses and other recreational areas. ARS scientists in Beltsville, Maryland, and Oregon State University collaborators used advanced cryo-scanning electron microscopy techniques to visualize cyst nematodes isolated from turf grass in Oregon. Using these techniques, a new cyst nematode species was discovered on turf grass in Oregon and was reported in the journal Nematology. This discovery is invaluable for scientists and turf management experts developing new methods to survey turf areas more quickly for this detrimental nematode and implement management practices to reduce turf damage. (NP303, Project No. 8042-22000-305-00D)

The *Septoria tritici* blotch pathogen of wheat senses and response to light. Scientists know that spores of plant-pathogenic fungi and associated toxin production can be influenced by light. But despite its great economic importance, nothing was known about the photobiology of the *Septoria tritici* blotch pathogen of wheat. ARS scientists in West Lafayette, Indiana, conducted testing on the *Septoria tritici* blotch pathogen to compare the gene expression of cultures grown under white, blue, or red light versus cultures grown in the dark. The results demonstrated that this fungus can sense and respond to different wavelengths of light, and identified some genes that are involved in pathogenicity. These results will be useful to plant pathologists managing *Septoria tritici* blotch on wheat and could help fungicide companies design better control strategies by targeting essential genes for sensing and responding to light. These results were published in BMC Genomics less than a year ago but have already been cited by others, which indicates the international interest and potential high impact of this research. (NP 303, Project No. 5020-21220-019-00D)

Screening for sunflower resistance to *Sclerotinia* basal stalk rot. Using field trials to evaluate sunflower resistance to *Sclerotinia* basal stalk rot is time consuming and offers limited resolution for identifying resistance. ARS scientists in Fargo, North Dakota, and colleagues at North Dakota State University and Iowa State University developed and validated a new greenhouse method using sclerotinia-infected millet seed to infect single sunflower plants to evaluate basal stalk rot resistance. The new method is time and space efficient and allows for disease evaluations in a single year, compared to multiyear, multilocation studies using inoculated field trials. Results from the new method were strongly correlated with field observations. This new method, published in the journal Plant Disease, will assist sunflower breeders and pathologists in their evaluation of sunflower genetic populations to improve the rapid identification of genomic regions associated with resistance to basal stalk rot. (NP 303, Project No. 3060-21220-031-00D)

Identification of novel variants to the sudden oak death pathogen. Sudden oak death is caused by the water mold *Phytophthora ramorum* and continues to invade U.S. forests. To control outbreaks in Oregon forests, forest managers need to understand how the pathogen is introduced and where it comes from. ARS scientists in Corvallis, Oregon, detected novel variants of the sudden oak death pathogen using genetic analysis. This analysis identified novel introductions of two clonal lineages into U.S. forests. This information provides insights for regulatory agencies and forest managers to understand pathways of introduction of the sudden oak death pathogen. (NP 303, Project No. 2072-22000-041-00D)

Link found between plant phenols and resistance to grapevine diseases. Fungal diseases and Pierce's disease of grapevines, caused by the bacterium *Xylella fastidiosa*, reduce grape yields. Progression of these diseases depends on specific metabolic plant-microbe interactions involving phenols, which can affect bacterial biofilm formation and fungal lesion lengths, but more information on links between plant metabolism and pathogens is needed. ARS researchers in Parlier, California, discovered that grapevine varieties producing less phenol in response to infection are less affected by fungal canker pathogens. Additionally, scientists found phenolic responses are also linked with grapevine resistance to Pierce's disease. Understanding these interactions will be useful for identifying new grapevine varieties that provide improved resistance to fungal pathogens. (NP 303, Project No. 2034-22000-012-00D)

Two for one: New technology detects two citrus pathogens in one test. Citrus greening is managed in California by intensive surveys and immediate eradication. Detecting citrus greening is complicated by the presence of citrus stubborn disease, which is caused by a different pathogen than the citrus greening pathogen. However, trees infected with either pathogen exhibit symptoms that are similar, resulting in misidentification and complicating citrus greening control and eradication efforts. ARS researchers in

Parlier, California, developed two different PCR tests that can rapidly differentiate between the two pathogens. These methods, published in the online journal PLoS One, provide clear quantitation of the pathogen(s), which is critical when there are only low concentrations of target DNA, and is critically important in regulatory programs involving mandatory eradication. (NP 303, Project No. 2034-22000-013-00D)

Origin of the wheat stem rust race group Ug99. The wheat stem rust pathogen *Puccinia graminis* f. sp. *tritici* continues to evolve and generate new races that threaten wheat production worldwide. The origin of new race groups of the wheat stem rust pathogen is likely due to recombination events between different races, but little is known about this process. Previous work by University of Minnesota scientists demonstrated that the Ug99 group was formed by the recombination of DNA between two races of *P. graminis* f. sp. *tritici* that did not involve the normal sexual cycle, which is called parasexual recombination, and identified one of the two races. ARS researchers in St. Paul, Minnesota identified the second race involved in the formation of the Ug99 group. A new method based on single molecule DNA sequencing in individual genes was used to identify one race as the most likely progenitor of the Ug99 group. This new method can be used for identifying parasexual recombination events in cereal rust fungi. Knowledge of how Ug99 originated and has evolved can be used to develop strategies to control and reduce yield losses in wheat due to stem rust. (NP 303, Project No. 5062-21220-023-00D)

NP 305 Crop Production

Winter oilseed cover crops suppress early season weeds. ARS researchers and university partners in Morris, Minnesota, are developing Midwest U.S. crop production systems that use winter camelina and pennycress as an oilseed cash cover crop that can also suppress the growth of weeds. They found

pennycress, as an overwintering crop, reduced spring and early summer weed growth from 97 to 100 percent, while winter camelina suppressed weeds from 85 to 87 percent. When used as cash cover crops, these oilseeds can reduce herbicide use and help control herbicide resistant weeds. These findings have been shared via a refereed publication and will greatly benefit farmers, agronomists, extension educators, and others interested in adopting this new cropping practice. (NP 305, Project No. 5060-21220-007-00D)

Natural compounds against major viral diseases in honeybees. There are currently no registered treatments or medicines that are effective against honeybee viruses and other microbes. Natural products that range from extracts of secondary compounds in plants and other living organisms to organic molecules provide a rich source of candidates for bee disease treatment. ARS scientists in Beltsville, Maryland, developed efficient and inexpensive screening techniques for testing new natural medicines for bees. Researchers discovered and patented several natural product compounds that are effective hive-based treatments against major bee viruses. These efforts expand the available options to control diseases for beekeepers, helping to ensure better colony health, pollination services and the production of honey, and other hive products. (NP 305, Project No. 8042-21000-291-00D)

A new and rugged ground-based method estimates crop water use. Farmers in the drought-stricken Western United States require better tools to improve precision irrigation management. Reliable ground-based sensors can complement efforts to quantify crop water use and measure crop stress remotely with satellites and drones. ARS researchers in Davis, California, along with University of California-Davis collaborators, found a way to utilize rugged infrared temperature sensors to measure crop water use and stress down to the single plant level. This new method determines crop water use by measuring changes in crop temperatures every second. The effectiveness of this new method was shown in vineyards and

tree crop orchards by comparing measurements against gold standard methods. This breakthrough enables the use of these durable, readily available sensors to improve precision irrigation management and environmental stewardship. (NP 305, Project No. 2032-21220-008-00D)

Flowers as hubs for the microbial symbionts of bees. Native bees are important for cranberry pollination and the role of floral substrates as the "hub" of microbial transmission among native bee fauna has been a focus of investigation by researchers. The survival of native bees depends on microbial symbionts within the pollen provision. Microbes are critical to the development of bee larvae, but the various mechanisms and key players have not been explored. ARS scientists in Madison, Wisconsin, showed that flowers serve as the pickup and dropoff sites for beneficial bacteria and yeasts. Microbial communities predigest the pollen grains within the larva's pollen provision. These symbiont microbes function much like those within the rumen of a cow, providing access to amino acids and lipids that would otherwise be unavailable to young developing bees. ARS scientists showed that these microbial communities are not specific to certain bee species, but rather are shared widely throughout bee species. The mechanisms of transmission are mediated by flowers in the landscape and ensure that critical microbial groups are harbored long enough to be broadly distributed among pollinator populations. This work is critically important for agriculture because pollinators are essential to fruit set and development. (NP 301, Project No. 5090-21220-004-00D)

Upgrades to an intelligent spray system for specialty crops. A commercially upgraded version of the intelligent spray system was developed by ARS scientists in Wooster, Ohio, in collaboration with Smart Guided Systems LLC. New features in the system includes tree counting, tree size, foliage density heat map comparison capability, liquid volume sprayed per plant, maps of sprayed plant locations, cloud sync feature, and other options. The upgraded commercial system has been used as a retrofit kit on

existing sprayers by U.S. growers and other countries for crops including citrus, nursery, pecan, blueberry, peach, almond, apple, pear, and grape. Pesticide usage reduction ranges from 30 to 85 percent, depending on crop types and growth stages. The John Deere Company now sells the commercial intelligent spray control system mounted on tractors for high-value crop applications. This environmentally sustainable product received the 2021 SIMA Gold Metal, which is the largest agricultural innovation award in Europe. In addition, the Permanent Crop Analyzer, a part of the commercial intelligent spray system, was awarded the 2021 Top-10 New Product winners by the World Ag Expo. (NP 305, Project No. 5082-21620-001-00D)

Elevated carbon dioxide and chronic high temperature or drought stress reduce nitrogen uptake in crop plants. Climate change is predicted to result in conditions that are warmer and drier, and that contain higher concentrations of carbon dioxide (CO_2). ARS scientists in Toledo, Ohio, and researchers from the University of Toledo found that plant stress induced by elevated CO_2 levels and chronic high temperatures negatively impacts tomato growth, nitrogen (N) uptake rates, and N transport from the roots to the shoots. They also demonstrated that elevated CO_2 levels and chronic high temperatures negatively impact N concentrations and reduce the protein content of wheat. Furthermore, researchers showed that, when coupled with drought-related stress, elevated CO_2 levels result in the reduction of plant phosphorous (P) levels, even though an increase in nutrient uptake transporters in the roots is meant to counteract such stresses. Collectively, these studies indicate that plant growth, yield, and quality will be negatively affected by predicted climate scenarios. These research findings will help plant breeders focus on developing improved and resilient cultivars that are well-suited for potential climate change conditions. (NP 305, Project No. 5082-21000-001-00D)

NATIONAL AGRICULTURAL LIBARY

The National Agricultural Library (NAL) is one of the largest and most accessible agricultural research libraries in the world. NAL provides services directly to the staff of USDA and to the public, primarily via the NAL website, www.nal.usda.gov. NAL's vision is "advancing access to global information for agriculture."

Ag Data Commons expands public access to USDA-funded data. The Ag Data Commons is a public data catalog and repository that helps the agricultural research community share and discover research data funded by USDA. Ag Data Commons works closely with the USDA research community to meet Federal open access requirements to support scientific integrity and data reuse. In FY 2021, Ag Data Commons registered an all-time high number of dataset submissions from ARS researchers and their extramural collaborators. A new collaboration was established with Partnership for Data Innovation to identify requirements for a protocols system supporting a more systematic approach to finding associations between data and methodology. The collaboration will continue in FY 2022.

Increasing USDA full-text publications and peer-reviewed citations in PubAg. PubAg is NAL's search system for USDA-funded scholarly agricultural literature and is the source for researchers, scientists, and the public to find scientific, peer-reviewed agriculture-related citations and publications. In FY 2021, PubAg reached 3,487,840 million citations to peer-reviewed, agriculture-related scientific articles, an increase of more than 437,063 citations from FY 2020. NAL also increased the full-text

corpus publicly accessible through PubAg by nearly 10,000 full-text articles, for a total of 311,877 full-text articles.

i5K Workspace. The i5K Workspace is a place for arthropod genome communities to curate, visualize, and share data about agricultural pests and other arthropods. In FY 2021, the total number of workspace users increased to 15,044, with 57,962 total annual page views. The i5k Workspace improved a functional annotation pipeline for arthropod genomes, added seven new genomes to its platform, and released five functional genome annotations to NCBI, with more slated for FY 2022. ARS i5k Workspace personnel also contributed to the Ag100Pest project in FY 2021 via upgrades that will support an initial assembly of 25 genomes.

Agricultural Law Information Partnership. The Agricultural Law Information Partnership supports the agricultural sector by providing resources and events on agriculture-related legal issues, programs, and emerging topics. This year the partnership, through lead collaborators at the Center for Agriculture and Food Systems at Vermont Law School and the National Agricultural Law Center with the University of Arkansas System, provided legal expertise in agricultural law issues related to COVID, carbon, agriculture and the environment, food labeling, food safety, and land access. The partners from Vermont Law School presented to the USDA Environmental Justice group on Food Systems and Environmental Justice. The partnership hosted two panels of guest speakers and Wikipedia edit-a-thons on the Food Safety Modernization Act and invasive species.

Hosting and disseminating USDA nutrition data. FoodData Central is an integrated data system that provides expanded nutrient profile data and links to related agricultural and experimental research. NAL hosted the FoodData Central website, providing online access to data for more than 383,713 different

foods with more than 18.5 million food component entries. Combined, the FoodData Central platform and the legacy Food Composition Database generated nearly 15 million pageviews during 2.1 million user sessions in FY 2021; and application developers from private industry and academia made nearly 36 million application programming interface (API) calls to FoodData Central, making the FoodData Central API among the most popular in Government. NAL made major improvements in the API application code that increased the efficiency of the query system.

Document delivery and interlibrary loan. NAL's Collection Management Contract staff continued to provide document delivery and interlibrary loan services during the pandemic, providing loans and copies of agriculture-related books and articles to USDA employees around the country. NAL also provided interlibrary loan service to other libraries across the United States and around the world. Interlibrary loan requests increased substantially as NAL became a go-to resource for other libraries during the pandemic.

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

Outreach Activity	Laboratory	Description
Field Day	Honeybee Breeding, Genetics, and Physiology Research, Baton Rouge, LA	Participated in a virtual Field Day and open house that was in conjunction with the Louisiana Beekeepers Association.
Field Day	Arid-Land Agricultural Research Center, Maricopa, AZ	Hosted their annual Farm Science Day event in a virtual format as part of the statewide AZ SciTech Festival.
Field Day	Plant Germplasm Introduction and Testing Research, Pullman, WA	Participated as a panelist during an Agricultural Field Day hosted by Columbia Basin College, Pasco, WA.
Field Day	Soil Drainage Research, Columbus, OH	Gave a presentation entitled "Legacy P Losses" at the Manure Science Review in Celina OH.
Field Day	Soil Dynamics Research, Auburn, AL	Gave a presentation entitled "Cover Crop Management" at the University of Florida Extension's Cover Crop and Soil Moisture Field Day, McDavid, FL.

Field Day	Soil Dynamics Research, Auburn, AL	Gave a presentation entitled "Nitrogen Credit From Legume Cover Crops" at the Alabama Extension's South Alabama Cover Crop Field Day.
Field Day	Sugarbeet and Bean Research, East Lansing, MI	Participated in Saginaw Valley Research and Extension Center's Bean and Beet Field Day.
Field Day	Sugarcane Research, Houma, LA	Participated in Louisiana State University AgCenter's Sugarcane Field Day, St. Gabriel, LA.
Presentation to Practitioner/Industry /Producer	Agroecosystems Management Research, Ames, IA	Presented a webinar on global change factors in eastern North and South Dakota and how that affects agroecosystem service delivery.
Presentation to Practitioner/Industry /Producer	Animal Genomics and Improvement Laboratory, Beltsville, MD	Participated in the International Committee for Animal Recording Functional Traits Working Group to discuss international standards for data recording and genetic evaluation.
Presentation to Practitioner/Industry /Producer	Application Technology Research, Wooster, OH	Gave a virtual presentation entitled "Identifying and Managing Soilborne Diseases in High Tunnels" in the Ohio State Specialty Crops Team and Ohio Controlled Environment Agriculture Center Virtual High Tunnel and Season Extension School.
Presentation to Practitioner/Industry /Producer	Corn, Soybean, and Wheat Quality Research, Wooster, OH	Gave research updates on progress towards "Pre-harvest Sprout Resistance in Soft Winter Wheat" at the virtual Soft Wheat Quality Laboratory Annual Research Review.
Presentation to Practitioner/Industry /Producer	Crops Pathology and Genetics Research, Davis, CA	Gave virtual presentations to almond grower and pest control advisor stakeholders on anaerobic soil disinfestation for almond replanting; etiology and management of *Phytophthora* diseases on almond; and development of almond rootstocks with improved resistance to *Phytophthora*.

Presentation to Practitioner/Industry /Producer	Crops Pathology and Genetics Research, Davis, CA	Interviewed on anaerobic soil disinfestation for University of California Cooperative Extension's Growing the Valley podcast.
Presentation to Practitioner/Industry /Producer	Floral and Nursery Plants Research, Washington, DC	Gave a virtual presentation entitled "Boxwood Breeding at the U.S. National Arboretum" at the Cultivate 21 meeting.
Presentation to Practitioner/Industry /Producer	Floral and Nursery Plants Research, Washington, DC	Gave a virtual presentation entitled "The U.S. National Arboretum - Helping Improve the Gardens of Today and Tomorrow" at the Annual Southeastern Plant Conference.
Presentation to Practitioner/Industry /Producer	Floral and Nursery Plants Research, Washington, DC	Gave a virtual presentation entitled "Plant Conservation and Evaluation at the U.S. National Arboretum Germplasm Repository" at the annual meeting of the Professional Grounds Maintenance Society.
Presentation to Practitioner/Industry /Producer	Honeybee Breeding, Genetics and Physiology Research, Baton Rouge, LA	Gave a presentation on amitraz resistance in *Varroa* to the Utah State apiary inspectors.
Presentation to Practitioner/Industry /Producer	Invasive Species and Pollination Health Research, Albany, CA	Gave a presentation entitled "The Enemy of My Enemy-Biocontrol" to the California Invasive Plant Council.
Presentation to Practitioner/Industry /Producer	Livestock Issues Research, Lubbock, TX	Trained Texas Tech University and West Texas A&M University students in: animal handling, blood collection, catheter placement, and associated laboratory analyses.
Presentation to Practitioner/Industry /Producer	New England Plant, Soil, and Water Research, Orono, ME	Gave a presentation entitled "Long-Term Effects of Different Potato Cropping Systems on Soil and Crop Health and Productivity" to potato researchers, growers, and industry representatives.

Presentation to Practitioner/Industry /Producer	New England Plant, Soil, and Water Research, Orono, ME	Gave a presentation entitled "Incorporating Disease-Suppressive Rotation Crops Into Potato Cropping Systems" at a University of Maine Cooperative Extension potato growers meeting.
Presentation to Practitioner/Industry /Producer	New England Plant, Soil, and Water Research, Orono, ME	Gave a presentation entitled "Cropping Systems and Their Effects on Soil Health, Soilborne Diseases, and Productivity" at the Oregon State University Extension's Hermiston Farm Fair, Hermiston, OR.
Presentation to Practitioner/Industry /Producer	Pasture Systems and Watershed Management Research, University Park, PA	Gave a presentation on the benefits of conservation practices in dairy forage production at the annual meeting of the Dairy Sustainability Alliance.
Presentation to Practitioner/Industry /Producer	Physiology and Pathology of Tree Fruits Research, Wenatchee, WA	Gave presentations entitled "Storage Management of 'Gala' and 'Honeycrisp' Apples in the Pacific Northwest USA" and "2020-21 Envy Apple Storage Performance" to industry field and warehouse personnel.
Presentation to Practitioner/Industry /Producer	Physiology and Pathology of Tree Fruits Research, Wenatchee, WA	Gave presentations entitled "Scilate Apple Research Report" to growers and industry research partners.
Presentation to Practitioner/Industry /Producer	Plant Science Research, St. Paul, MN	Gave a presentation entitled "Alfalfa Root Rots: Past, Present and Future" at the Idaho Hay and Forage Growers Conference.
Presentation to Practitioner/Industry /Producer	Plant Science Research, St. Paul, MN	Gave a presentation entitled "Sustainable Protein Source for Aquaculture Feeds From Alfalfa" at the Midwest Forage Association Symposium on new uses for alfalfa.
Presentation to Practitioner/Industry /Producer	Plant Science Research, St. Paul, MN	Gave a presentation entitled "Midwestern-Eastern U.S. Alfalfa Yield Limitations: Diseases" at the CROPlan Alfalfa Training Seminar.

Presentation to Practitioner/Industry /Producer	Plant Science Research, St. Paul, MN	Gave a presentation entitled "Key Diseases and Management in Alfalfa" at the Alfalfa Pest Workshop for the Western Alfalfa and Forage Association Symposium.
Presentation to Practitioner/Industry /Producer	Plant Science Research, St. Paul, MN	Presented information on alfalfa diseases, insect pests, and weeds at the National Alfalfa and Forage Alliance's Alfalfa Intensive Training Seminar.
Presentation to Practitioner/Industry /Producer	Range Sheep Production Efficiency Research, Dubois, ID	Hosted six international virtual programs aimed at increasing the production efficiency of sheep enterprises.
Presentation to Practitioner/Industry /Producer	Range Sheep Production Efficiency Research, Dubois, ID	Consulted on sheep production and rangeland management to over 100 producers.
Presentation to Practitioner/Industry /Producer	Range Sheep Production Efficiency Research, Dubois, ID	Gave presentations entitled "Flock Health Management: Fine-tuning Vaccination Programs" and "Functional Shed-Lambing Systems: Infrastructure, Management, and Health" to sheep and goat producers, practitioners, educators, and consultants from 13 countries. The webinar was hosted by the University of Idaho and University of Wyoming Extension Programs.
Presentation to Practitioner/Industry /Producer	Soil Drainage Research, Columbus, OH	Gave a presentation entitled "Contributions of Legacy Soil P and P Fertilizer to Edge-of-Field P Losses" at the North Central Region Water Network's Virtual Harmful Algal Bloom Research Symposium.
Presentation to Practitioner/Industry /Producer	Soil Drainage Research, Columbus, OH	Gave a presentation on edge of field data to stakeholders from Natural Resources Conservation Service, Ohio Farm Bureau, Ohio State, and Wright State.
Presentation to Practitioner/Industry /Producer	Sugarbeet and Bean Research, East Lansing, MI	Gave a presentation entitled "Anatomy of the Bean: Dry Bean Breeding and Production for Consumer Acceptance" at the Michigan Bean Commission's webinar for dieticians.

Presentation to Practitioner/Industry /Producer	Sugarbeet and Bean Research, East Lansing, MI	Gave a presentation entitled "USDA-ARS Food Legume Genetics" to the American Pulse Association Board.
Presentation to Practitioner/Industry /Producer	Sugarcane Research, Houma, LA	Gave a presentation entitled "Sugarcane Entomology Update" in conjunction with Louisiana State University sugarcane and rice entomologist at the Louisiana Agricultural Technology and Management Conference.
Presentation to Practitioner/Industry /Producer	Sugarcane Research, Houma, LA	Gave a presentation entitled, "Adapting the Successful Sugarcane Borer IPM Program for Mexican Rice Borer Management" in conjunction with Louisiana State University sugarcane and rice entomologist at the joint meeting of the American Society of Sugar Cane Technologists and American Sugar Cane League.
Stakeholder Meeting	Animal Genomics and Improvement Laboratory, Beltsville, MD	Participated in a meeting with the National Association of Animal Breeders to discuss research on the "1000 Bull Genomes" project.
Stakeholder Meeting	Horticultural Crops Research, Corvallis, OR	Gave a presentation on cranberry phenolics to cranberry stakeholders.
Tour(s)	Clay Center, Clay Center, NE	Gave a tour of the Center to stakeholders.
Stakeholder Meeting	Clay Center, Clay Center, NE	Gave research presentations to the National Cattlemen's Beef Association
Stakeholder Meeting	Pest Management and Biocontrol Research, Maricopa, AZ	Arid-Land Agricultural Research Center hosted a bi-annual Stakeholder Meeting, representing industry, academics, and local farmers.
Stakeholder Meeting	Physiology and Pathology of Tree Fruits Research, Wenatchee, WA	Hosted Soil Health Initiative Long-Term Agricultural Research Site Stakeholder Advisory Meeting.
Stakeholder Meeting	Physiology and Pathology of Tree Fruits Research, Wenatchee, WA	Gave presentations at the Washington Tree Fruit Research Commission and the Washington State Tree Fruit Association Annual Meeting.

Stakeholder Meeting	Physiology and Pathology of Tree Fruits Research, Wenatchee, WA	Gave a presentation entitled "Linking Microbial Taxa with Function in Artificially Structured Apple Rhizosphere Microbiomes" at the Washington State Tree Fruit Association annual meeting.
Stakeholder Meeting	Range Management Research, Las Cruces, NM	Gave an annual research update of collaborative long-term monitoring of restoration treatments in southwest New Mexico to Bureau of Land Management, Natural Resources Conservation Service, and New Mexico Association of Soil and Water Conservation District.
Stakeholder Meeting	Range Management Research, Las Cruces, NM	Gave a presentation in a meeting organized by the Grameen Foundation.
Tour(s)	Temperature Tree Fruit and Vegetable Research, Wapato, WA	Gave a tour with informal overviews of research activities and goals to the Washington Tree Fruit Commission.
Tour(s)	Wheat health, Genetics, and Quality Research, Pullman, WA	Gave a tour to the Nisshin Trade Team to discuss 2021 crop quality, customer needs, and ongoing collaboration.
Training/Demo	Floral and Nursery Plants Research, Washington, DC	Presented training to at the virtual Collections Network Reviewer Training Symposium hosted by American Public Gardens Association.
Training/Demo	National Agricultural Library, Beltsville, MD	Demonstrated and provided training on using the Leadership Connect directory to identify individuals and organization across the Congress, Federal and State government, along with media sources.
Training/Demo	National Agricultural Library, Beltsville, MD	Provided training on using the EndNote citation management software.
Training/Demo	Livestock Issues Research, Lubbock, TX	Provided training to Texas Tech University students and a professor with respect to collecting animal behavior data.

Training/Demo	Livestock Issues Research, Lubbock, TX	Provided training to Texas Tech University students and industry volunteers in the collection and processing of samples to isolate enteric bacteria.
Training/Demo	Livestock Issues Research, Lubbock, TX	Provided training to Texas Tech University students in aseptic sample collection techniques, media preparation, waste decontamination and disposal, and all associated microbiological laboratory techniques and analyses associated with isolating bacteria from beef cattle samples.
Training/Demo	Livestock Issues Research, Lubbock, TX	Provided training to Texas Tech University students in animal handling, blood collection, jugular catheter placement, rectal temperature probe placement and associated laboratory analyses.
Training/Demo	Range Management Research, Las Cruces, NM	Provided training on a new tool for the development of State and transition models at the Society for Range Management virtual meeting.
Training/Demo	Soil Dynamics Research, Auburn, AL	Provided training on "Cover Crops and Herbicide Resistant Weed Management" at Auburn University Lead Certified Crop Advisor Training.
Training/Demo	Sugarbeet and bean Research, East Lansing, MI	Taught a class on disease diagnosis in sugar beet to students at the Michigan Sugarbeet Youth Day.
Workshop	Animal Genomics and Improvement Laboratory, Beltsville, MD	Gave a poster presentation and oral presentation about the FarmGTEx project at the Ruminant Genetics and Genomics Workshop of the Virtual International Society of Animal Genetics meeting.
Workshop	Animal Genomics and Improvement Laboratory, Beltsville, MD	Gave a presentation on the Cattle GTEx Project at the Breeding and Genetics Section of the American Dairy Science Association virtual annual meeting.

Workshop	Crop Diseases, Pests, and Genetics Research, Parlier, CA	Created online instructional videos on wiring insects, instrument set-up and use for AC-DC electropenetrography of plant-feeding insects and vectors of plant pathogens for the University of Florida Extension.
Workshop	Great Basin Rangelands Research, Reno, NV	Collaborated with experts from the Asian Development Bank's Knowledge & Experience Exchange Program, Michigan State University, and the Kazakhstan National Agrarian University to achieve rangeland assessment, integrated assessment of soil, water/vegetation conditions in the Akmola region, as well as specialized capacity building to support strategic objectives of the beef livestock sector.
Workshop	Great Basin Rangelands Research, Reno, NV	Collaborated with ARS scientists in Tucson, AZ, along with Natural Resources Conservation Service and United Nations Food & Agriculture Organization scientists on workshop to demonstrate technologies to identify rangelands at risk of degradation for the Kazakh National Agrarian University in Alamty, Kazakhstan.
Workshop	Physiology and Pathology of Tree Fruits Research, Wenatchee, WA	Held a question-and-answer session with tree fruit personnel regarding postharvest issues of apple and pear fruit.
Workshop	Plant Science Research, St. Paul, MN	Presented sections on alfalfa diseases, insect pests and weeds for the Alfalfa Intensive Training Seminar sponsored by the National Alfalfa and Forage Alliance.
Workshop	Range Management Research, Las Cruces, NM	Held workshop on climate data jam at the Environmental Changemakers Institute at Fort Lewis College

Workshop	Range Management Research, Las Cruces, NM	Held workshop on water conservation data jam at the New Mexico Science, Technology, Engineering, and Math Symposium.
Workshop	Sustainable Water Management Research, Stoneville, MS	Served as a subject matter expert in the Geodesign Games for Adaptive Futures hosted by Texas A&M and South-Central Climate Adaptation Science Center.

3.8. FY 2021 Technology Transfer Award Winners

ARS Technology Transfer Award

Laboratories: Conservation and Production Research Laboratory (Bushland, TX), Sustainable Agricultural Systems Laboratory (Beltsville, MD), Coastal Plain Soil, Water and Plant Conservation Research Unit (Florence, SC), Cropping Systems and Water Quality Research Unit (Columbia, MO), and Sustainable Water Management Research Unit (Stoneville, MS).

Title: Sensor-Based Automatic Variable Rate Irrigation Control Team.

Federal Laboratory Consortium for Technology Transfer (FLC) Awards

Laboratory: Cotton Chemistry and Utilization Research (New Orleans, LA)

Title: Cotton Wound Dressings for Battlefield Trauma and Prolonged Field Care

Award: National, Excellence in Technology Transfer

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

Title: Recovery of Ammonia from Waste Using Gas-permeable Membranes

Award: National, Excellence in Technology Transfer

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

Title: Recovery of Ammonia from Waste using Gas-permeable Membranes

Award: Southeast Region, Excellence in Technology Transfer

Laboratory: Cotton Production and Processing Research (Lubbock, TX)

Title: VIPR System for Removing Plastic Contamination During Cotton Ginning Process

Award: National, Excellence in Technology Transfer

Laboratory: Cotton Production and Processing Research (Lubbock, TX)

Title: VIPR System for Removing Plastic Contamination During Cotton Ginning Process

Award: Mid-Continent Region, Excellence in Technology Transfer

Laboratory: Invasive Species and Pollinator Health Research (Albany, CA)

Title: Delta Region Areawide Aquatic Weed Project (DRAAWP)

Award: Far-West Region, Outstanding Partnership

Laboratory: Animal Health Genomics Research (Clay Center, NE)

Title: Application of Interspecies Cross to Improve Efficiency of Genome Assembly

Award: Mid-Continent Region, Outstanding Partnership

Laboratory: Cell Wall Biology and Utilization Research (Madison, WI)

Title: Tools for Identifying Host Microbes for Viruses and Antimicrobial Resistance

Award: Midwest Region, Excellence in Technology Transfer

3.9. Selected Metric Charts.

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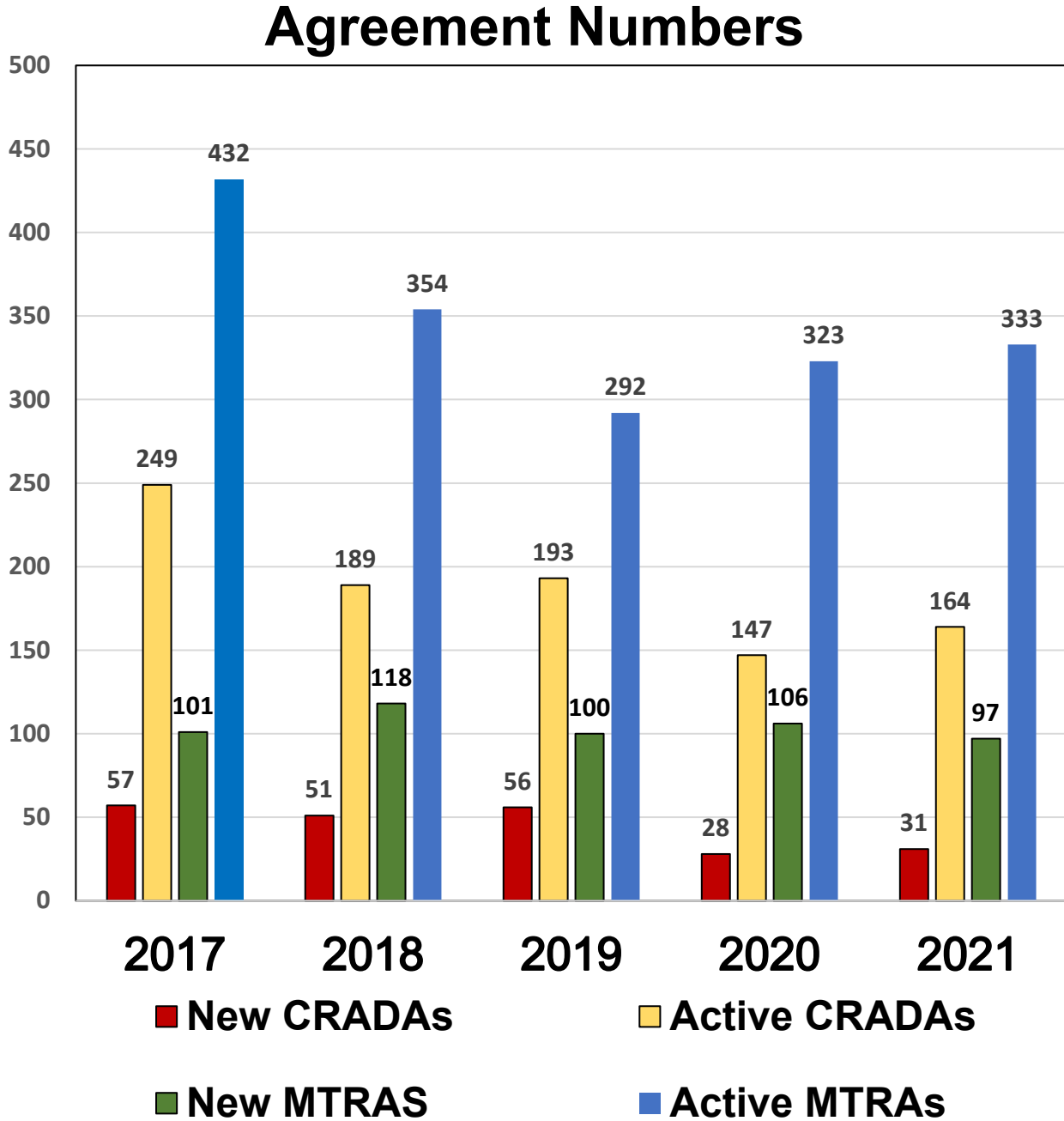
Agreement Numbers

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 2021.
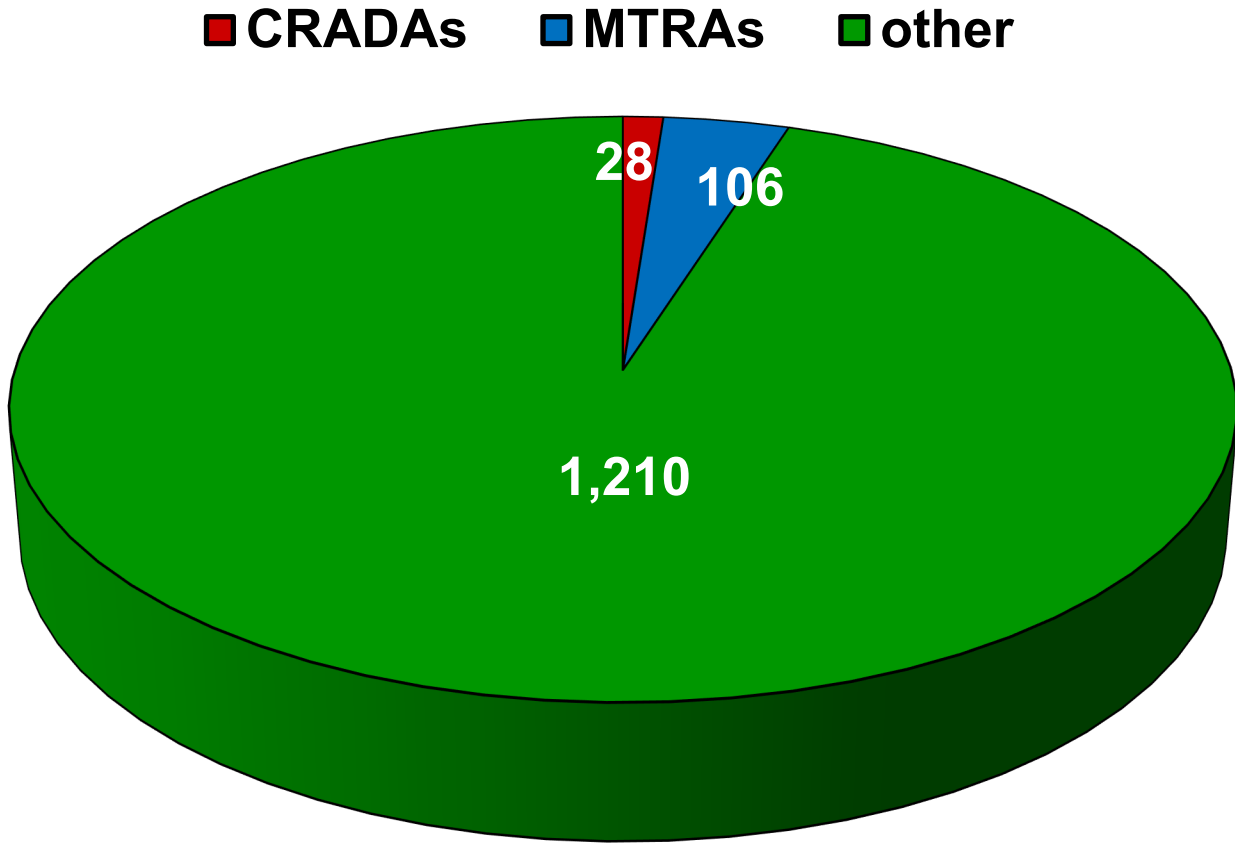
Figure 3. Number of invention disclosures, patent applications filed, and patents issued. The year in which a patent issues is not the year in which the patent is filed. The increase in the number of invention disclosures in FY 2018 was the result of a significant increase in biological materials disclosures.
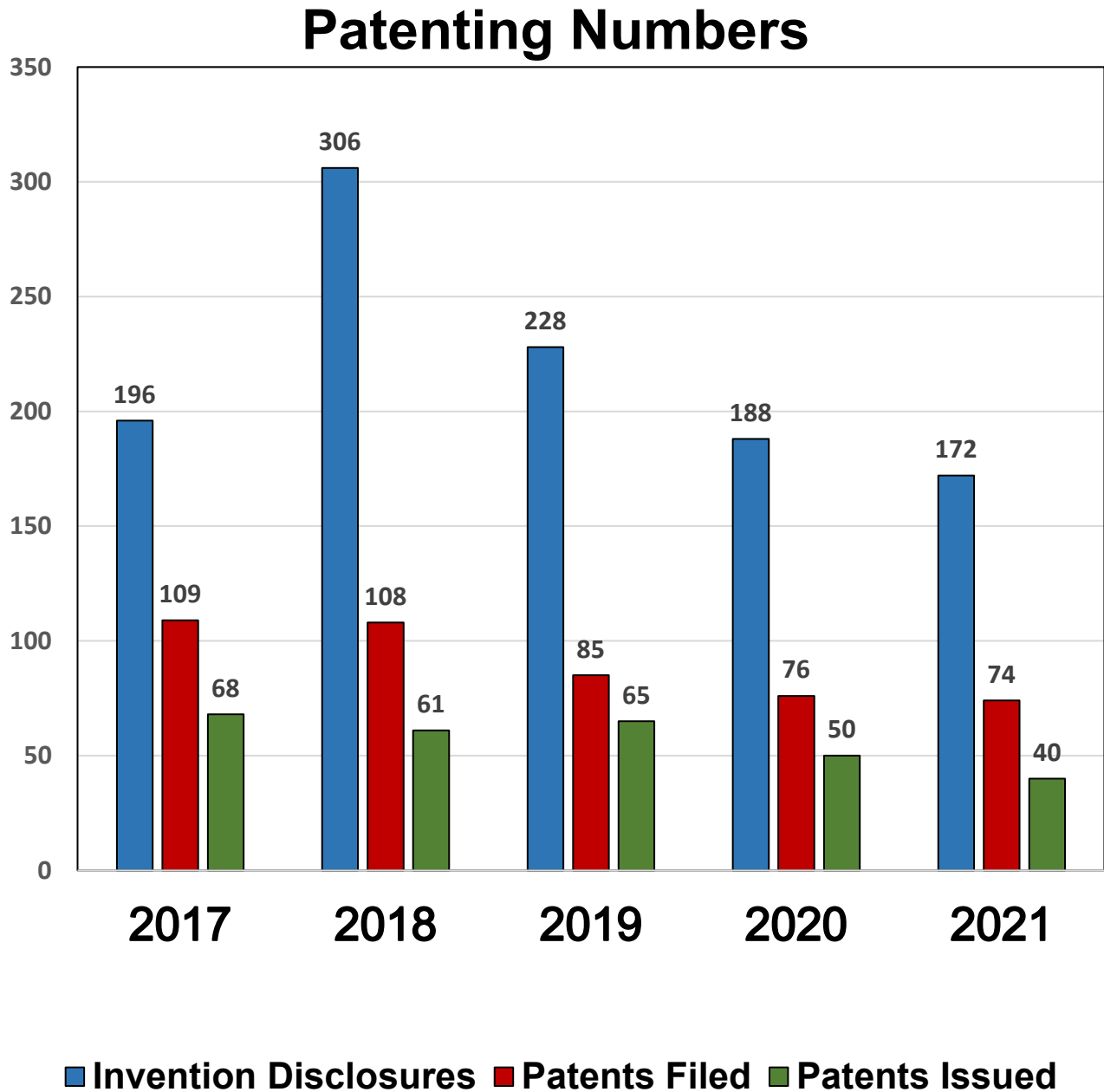
Figure 4. Percentage of patents issued in FY 2021 by scientific discipline.
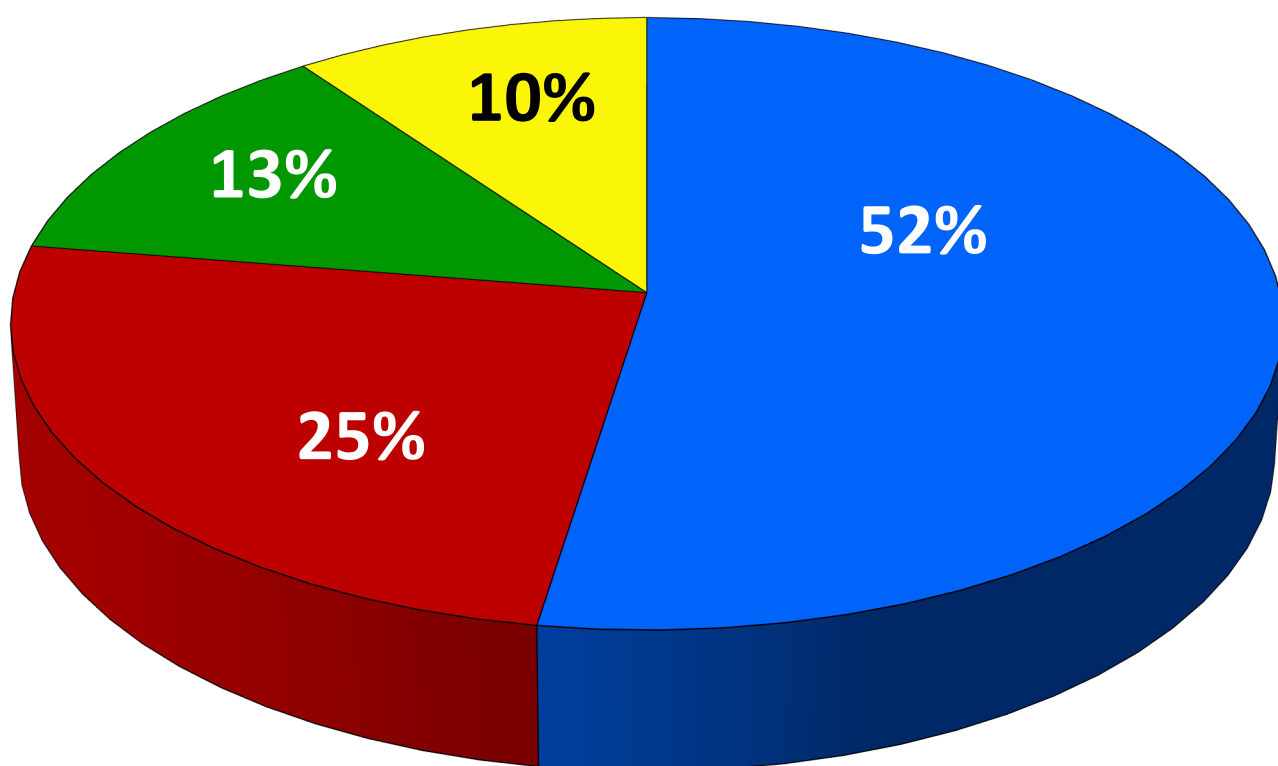
Figure 5. The ratio of patents issued over patent applications filed per year. Although the year in which a patent is issued is not typically the year in which the patent application is filed, over time the ratio of patents issued over the number of patent applications filed is an indicator of "judicious" patenting. Over the last 5 years, this indicator suggests that ~62 percent of the patent applications result in an issued patent.
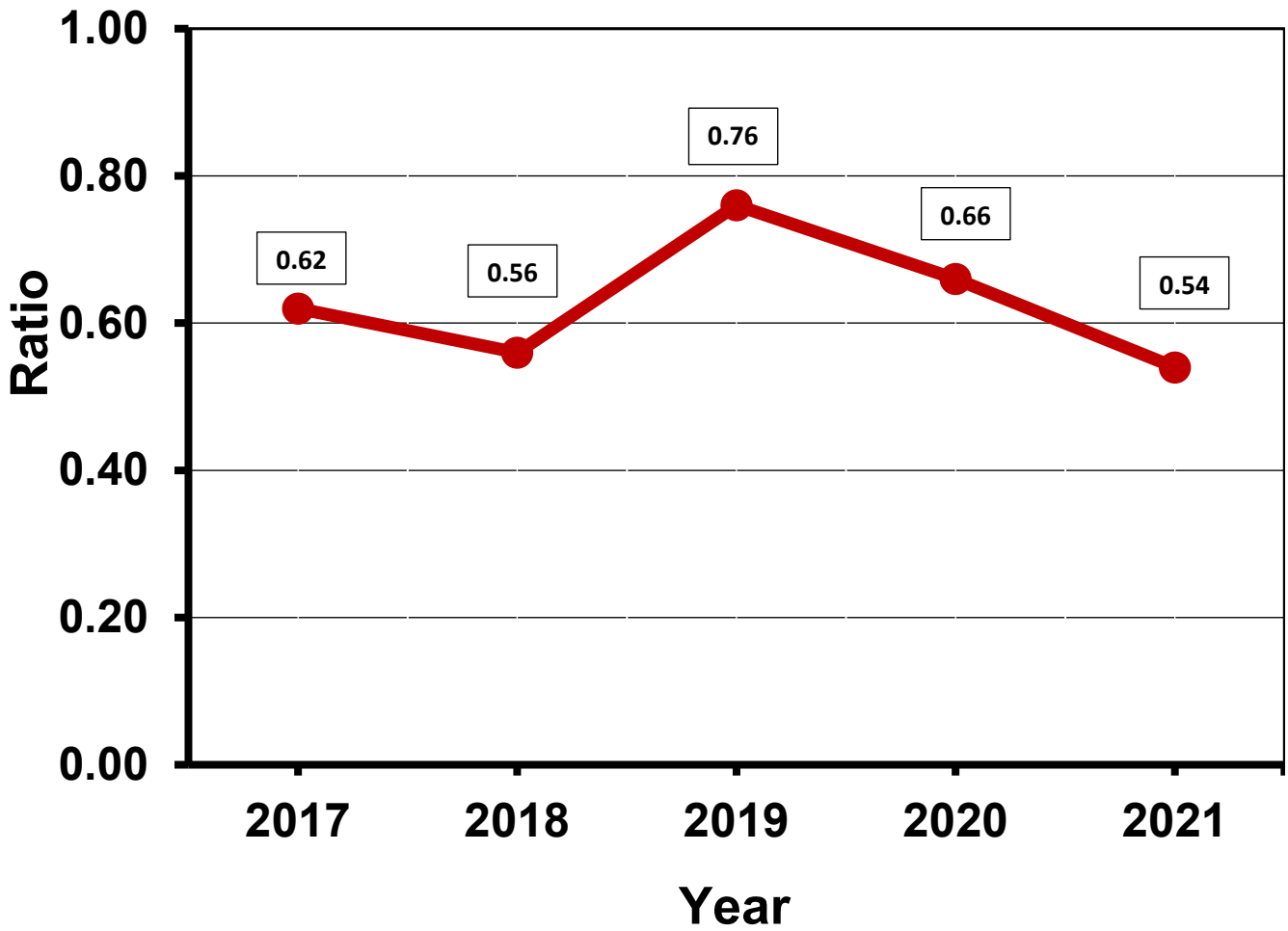
Figure 6. Number of license types per year
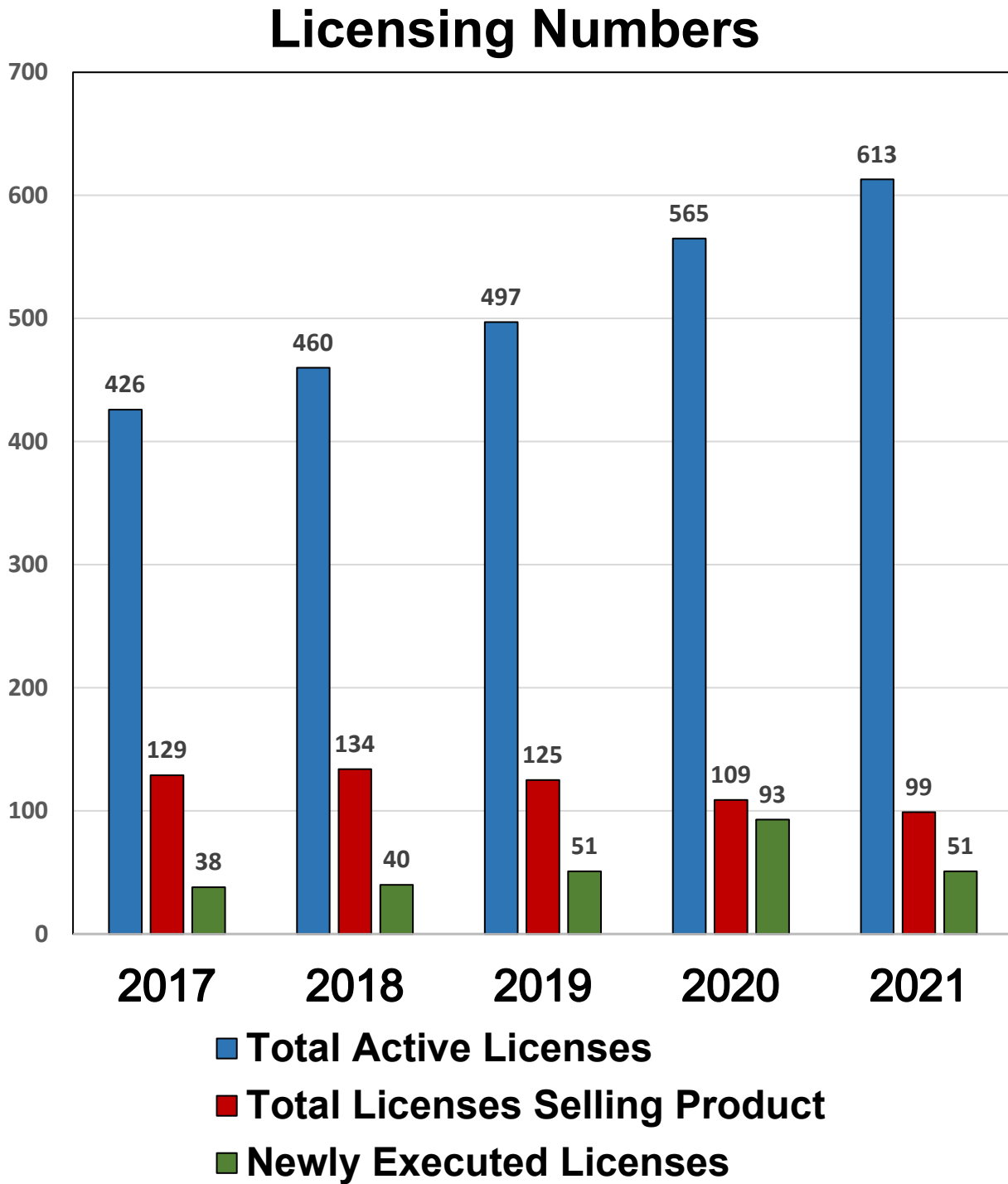
Figure 7. Earned license royalty income (ERI) over time. The lower income in FY 2018 and FY 2020 was due to several of the top revenue generating licenses expiring in FY 2017 and 2019.
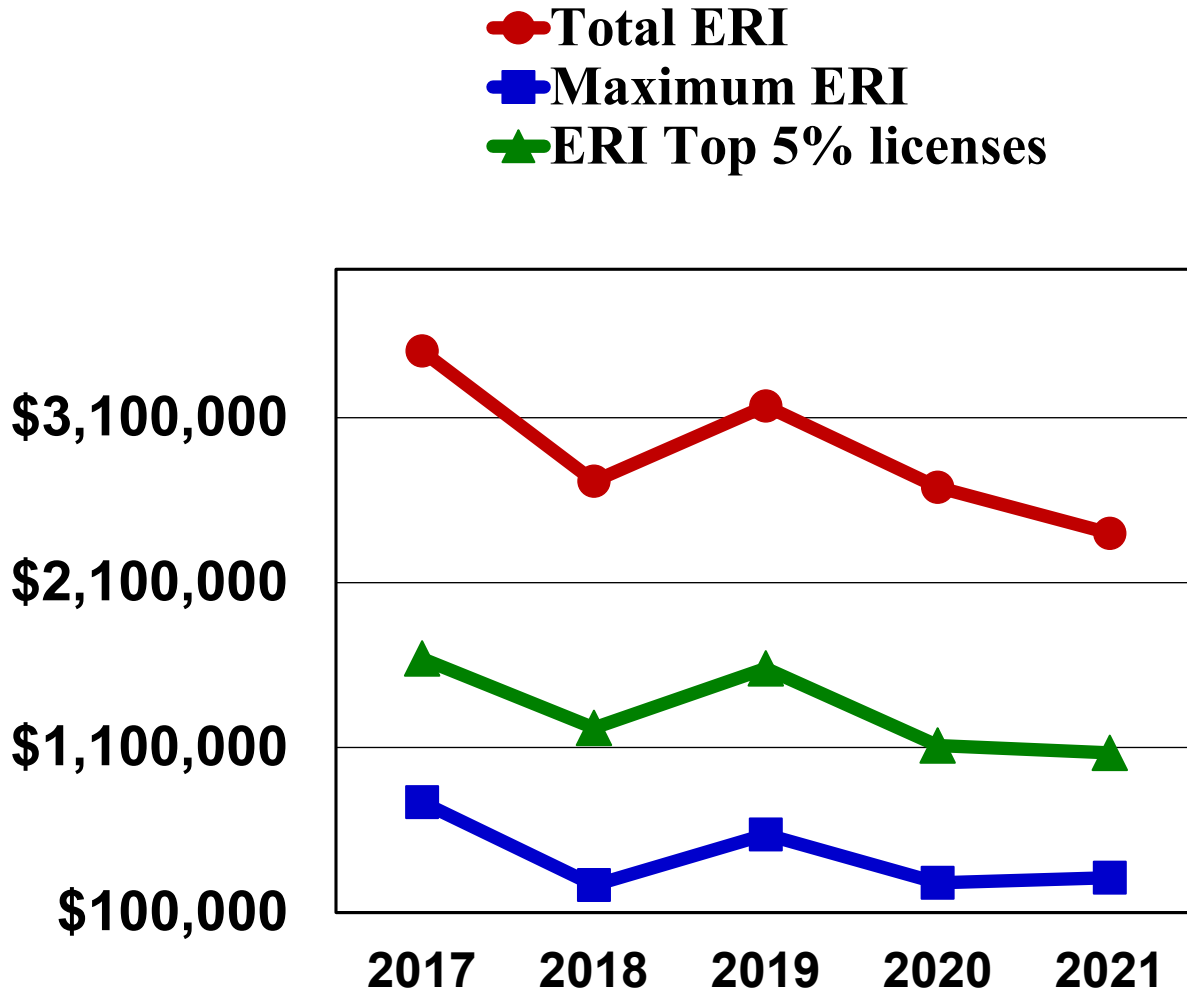
Figure 8. The percentage of new licenses executed in FY 2021 by business type.
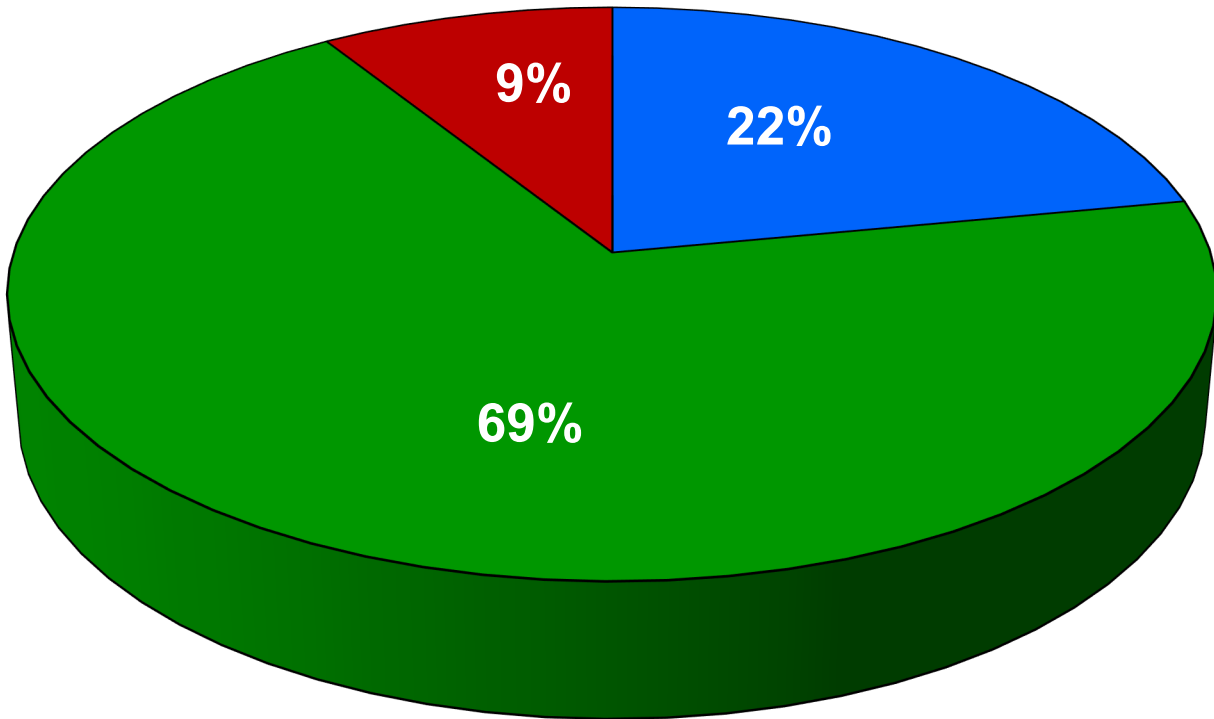
Figure 9. The ratio of newly signed invention licenses over newly issued patents per year. Although the year in which a license is signed is not typically the year in which the patent has issued, over time the ratio of newly signed licenses over the number of newly issued patents is an indicator of "judicious" patenting contemplating among other things commercial viability of the technology.
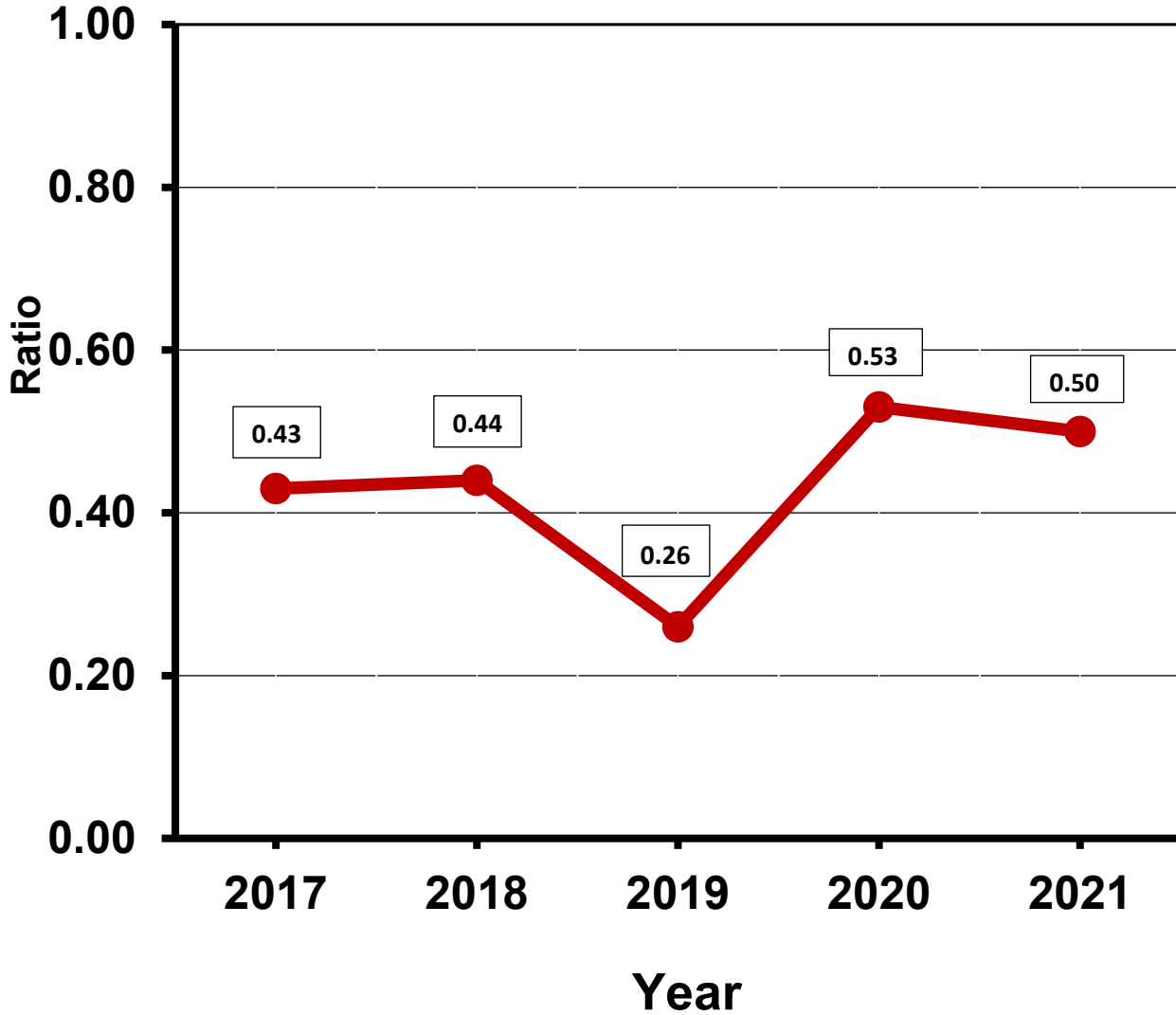
Figure 10. Number of publications per year

	Scientific Journal	Trade Journal
■ 2017	4,467	66
■ 2018	4,138	68
■ 2019	3,816	48
■ 2020	3,933	30
■ 2021	3,935	104
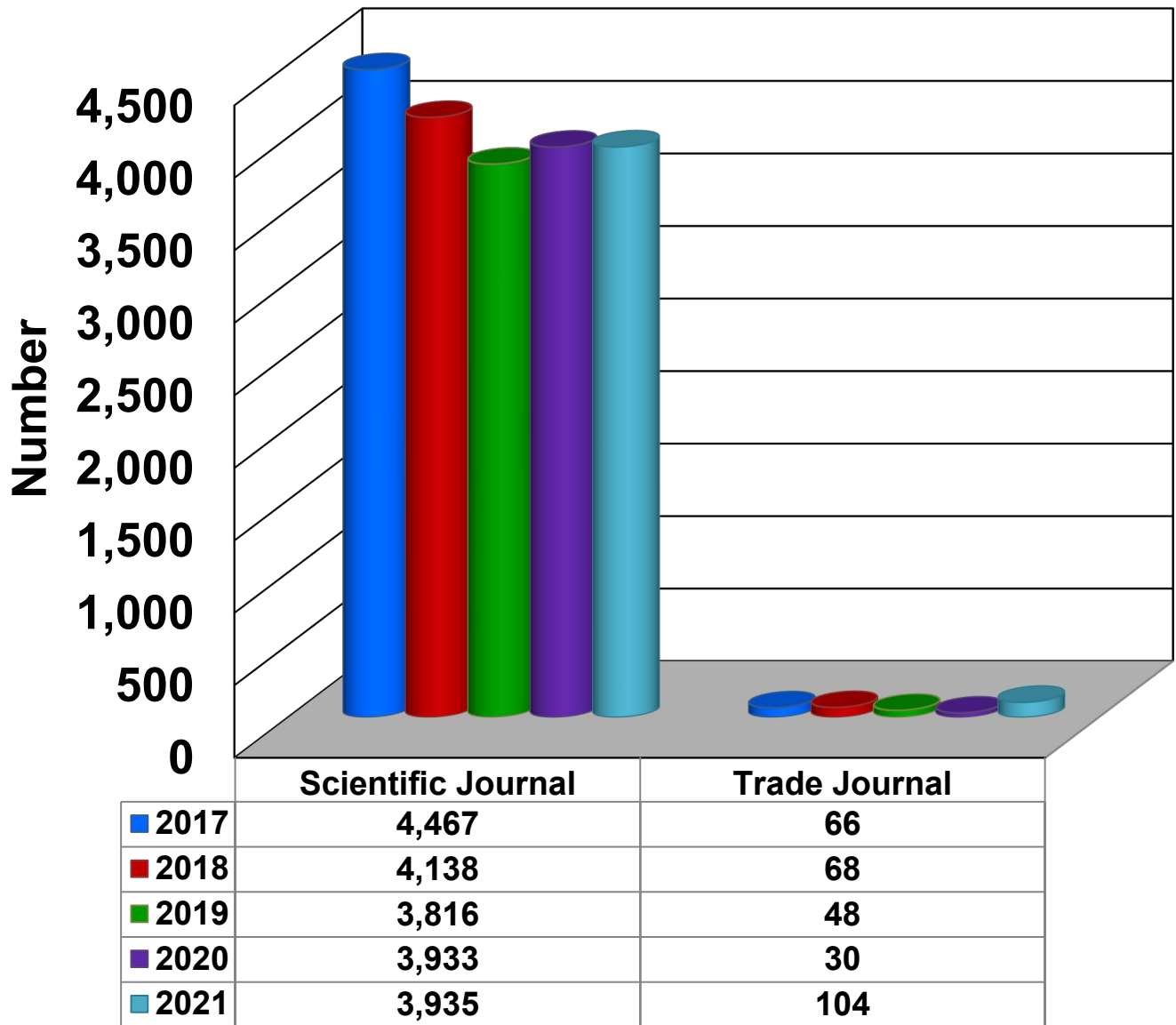
4.0. Economic Research Service (ERS)

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 provides crucial market and trade outlook information to help farmers and agricultural companies run successful businesses and support jobs.

ERS is the primary source of economic analysis and 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 1 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, 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 and 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, nongovernmental organizations, and the general public. All ERS research, data, and other information disseminated by the agency are available online 24/7 through the ERS website. 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, USA Search, Constant Contact, and the Verint (formerly 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. A major ERS 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.

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 data visualizations to enhance the communication value and information delivery to customers. ERS's concerted efforts also improved on-time posting 3 percentage points to 98 percent and led to a 3-percent increase in the Customer Satisfaction index score to 77 percent. Website Section 508 Accessibility continues to steadily improve.

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 2021, ERS continued expanding the use of several tools designed to help consumers more easily access critical programs and stimulate further innovation:

- **ERS Social media**: **ERS's Twitter feed** continues to expand the audience for ERS information, growing to over 45,000 followers in FY 2021, up from 35,000 followers in FY 2020, 32,000 followers in FY 2019, and 29,000 followers in FY 2018. ERS is now also on LinkedIn with more than 1,000 followers.

- **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 implemented ESRI story maps that integrate maps, legends, text, photos, and video to help users explore geospatially connected themes.

- ERS also continued to provide **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," prebuilt 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]() . 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. In FY 2021, ERS created new ESRI Story map for the public website presenting another medium to share the Food Access and Research Atlas (FARA) data.

- 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. 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 10 webinars in   2021 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 200 people participated in each of these webinars in FY 2021. 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 2021, ERS produced 151 peer-reviewed research reports and Outlook reports.

ERS Peer-Reviewed Research Reports

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
151	150	147	145	152	151	151	132	130	151
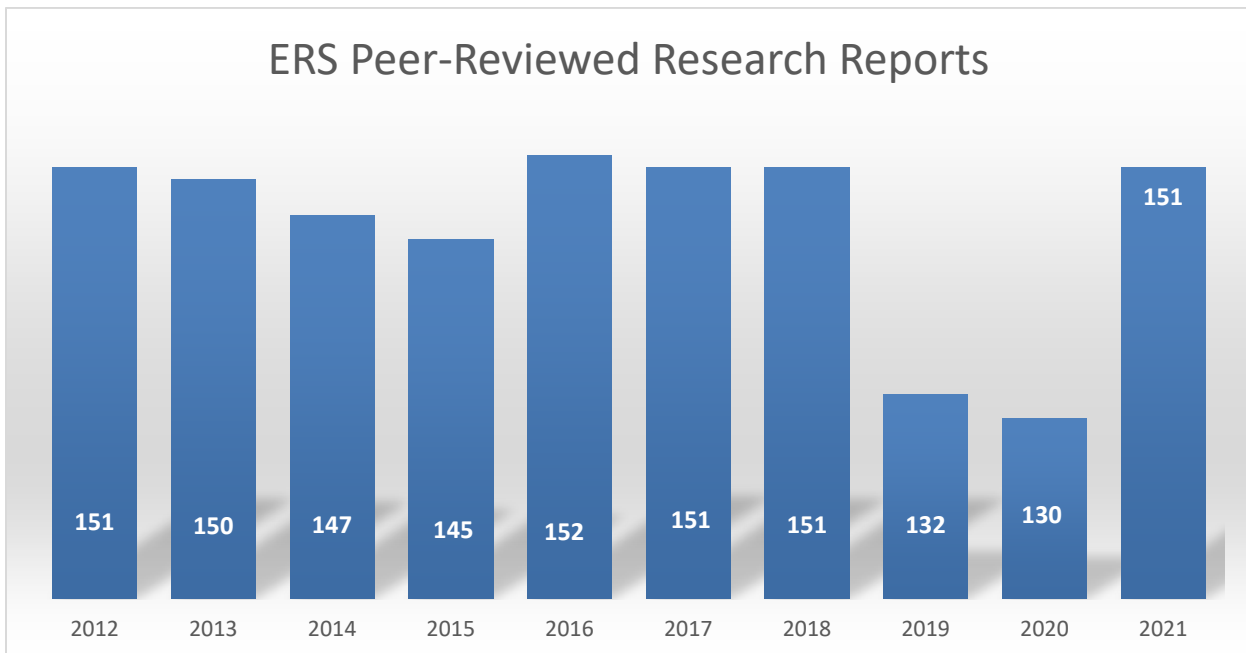
5.0.   Foreign Agricultural Service (FAS)

5.1.   Mission Statement

FAS's mission is to link U.S. agriculture to the world to enhance export opportunities and global food security.

5.2.   Nature and Structure of Program

FAS Washington, DC 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 70 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, nonemergency food assistance programs, and other technical assistance.

5.3.   Downstream Outcomes

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

Global Residue Project

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 2021, the project continued work with stakeholders 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.

Geographical Information System Mapping for Optimized Cacao Production in Colombia

In March 2021, under the Cacao for Peace (CfP) project in Colombia—managed by USDA, FAS and funded by the U.S. Agency for International Development—USDA, FAS, and its partners USDA, Natural Resources Conservation Service (NRCS), Pennsylvania State University, and Alliance Bioversity International-CIAT presented a CfP-financed geographical information system (GIS) web application to Colombian government technical agencies and other stakeholders. The web application contains soil, water, and cacao genetic information to assist Colombian farmers and policy makers make informed cultivation decisions. The Colombian government agencies expressed interest in adopting the tool and feeding it with additional data of their own. The CfP team of experts collected soil and cacao samples from the Sierra Nevada de Santa Marta region of Colombia. The team analyzed the samples and created a database used by NRCS to create the GIS web application in English and Spanish.

Technology transfer through collaborative research with Colombia under the Cacao for Peace project

In FY 21, under the Cacao for Peace project—managed by USDA, FAS and funded by the U.S. Agency for International Development—the project's research partners published two peer-reviewed scientific articles in the high-impact scientific journal Chemosphere. The first article was developed through a collaboration between Cacao for Peace Fulbright scholar Jhony Benavides Bolaños and Pennsylvania State University researchers and published in the February 2021 issue of Chemosphere. The article evaluates cadmium remediation materials finding that sunflower is the best phytomanagement species given its overall performance.
(https://www.sciencedirect.com/science/article/pii/S0045653520332835?via%3Dihub).

The second article was developed and published in Chemosphere's March 2021 issue through a collaboration between scientists from Colombia's agricultural research service Agrosavia, USDA's Agricultural Research Service (ARS), and the University of Florida (UFL). In the article, activated dolomite phosphate rock (DPR), acid activated dolomite phosphate rock (ADPR) and biochar were compared for immobilizing metals in two soils. The article's main findings are listed below:

- The immobilizing effectiveness (immobilization of cadmium and lead) of amendments varied with metal and soil type.

- Activation with humic acid increased the immobilizing power of DPR for cadmium (Cd^{2+}) and lead (Pb^2)+.

- The immobilization of metals by ADPR is related to increased soil pH and available phosphorus (P).

6.0. Forest Service

U.S. Department of Agriculture (USDA), <u>Forest Service Research and Development (R&D)</u> is a world leader in forestry research. Integral to the mission of the Forest Service since the agency's inception in 1905, R&D studies the most pressing natural resource management issues of our day, generating science findings and tools that help sustain the health, diversity, and productivity of our national forests and grasslands—and ultimately enhance the rigor and impact of the entire agency.

6.1. Understanding

Technology transfer ("tech transfer") and science delivery at the USDA Forest Service R&D, with the goal to enhance the utility of scientific information, is defined as *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 research is simple. Land managers, forest managers, city planners, and policymakers 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 codevelopment of knowledge together with practitioners and decisionmakers. Science delivery and tech transfer describe a linear process where science is conducted, knowledge is gained by scientists, and then is provided to the endusers as a final step. In contrast, our scientists are bringing knowledge users, stakeholders, and decisionmakers into the science process from the very beginning, a process that includes feedback loops. In today's Forest

Service, this codevelopment 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 design solutions.

6.2. Mission Statement

The overall mission of the Forest Service 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 Forest Service is an agency within the 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 ***Forest Service is the only land management agency in the USDA***. Gifford Pinchot, the first Chief of the Forest Service, summarized the mission of the Forest Service as *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), R&D, State and Private Forestry (S&PF), Business Operations, and Work Environment and Performance.

The R&D leadership's intent is for research to enhance the rigor and impact of the entire 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 the 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 the Nation's forests and grasslands;

- inform natural resource 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, nongovernmental 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 or primary 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, which contains 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 Framework

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

Research Priority Areas

- Applied science to support shared stewardship and improve forest conditions.

- Forest inventory and trend analysis.

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

- Wood product and market innovations.

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, working in a range of biological, physical, and social science fields to promote sustainable management of the Nation's diverse forests and rangelands. Their research covers a lot of territory, with programs in all 50 States, U.S. territories, and commonwealths. This structure provides sites for long-term research and management studies of major vegetation types found across the United States, as well as diverse research areas operated in collaboration with partners. The Forest Service 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 area of the Forest Service, there are also two Technology and Development Centers operated by NFS, located in Missoula, Montana and San Dimas, California.

Forest Service Research Stations

(U.S. Pacific Island Territories Not Pictured)

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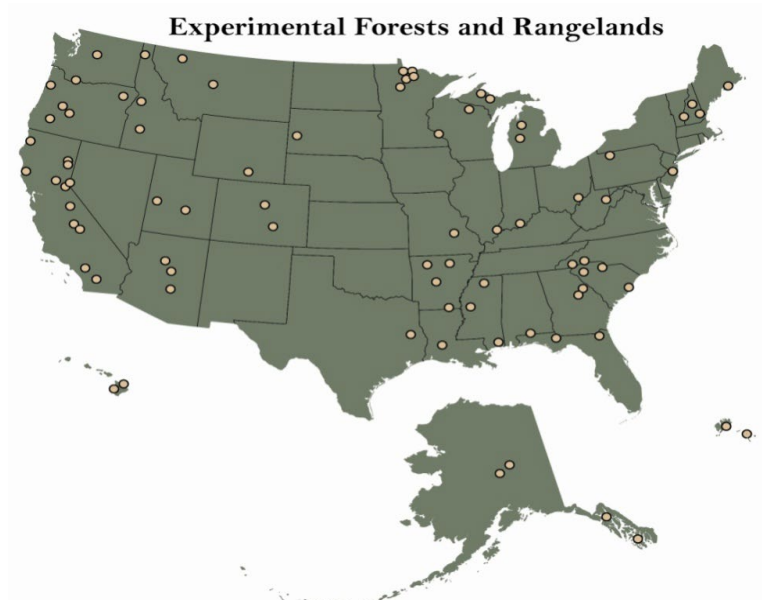
6.4. Role of the National R&D Office, Staff Directors, and National Program Leaders

The Washington Office of R&D 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 the 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 nonprofit organizations and professional and technical associations.

While national program leaders 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 Washington Office funds to coordinate research inputs among

Station scientists and to support grant programs in accordance with specific Washington Office 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 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 engagement, web visits, and citation indices. One major improvement to the technology transfer program in 2022 will be the addition of contract docketing program support. The program also is working to better support the Lab-To-Market technology transfer goals by working directly with funding recipients on intellectual property (IP) ownership and development by no longer working through iEdison. This change will improve the entire Forest Service IP partnership interaction.

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 and is located at the Washington Office-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, 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 Agriculture Research Service Office of Technology Transfer. Forest Service commercial licenses are royalty-based only, with the valuation 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, the Forest Service 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. The 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 NFS and S&PF, 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 wood resources. The long-term health of the 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 the 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 multistory 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 2021 Research Highlights

Moving toward understanding the mechanism of copper tolerance

Brown-rot basidiomycete decay fungi are the greatest threat to wood products in service because they can reduce the effectiveness of copper-containing wood preservatives. It is critical to study the

mechanism of copper tolerance to prevent copper-treated wood deterioration by these fungi. The goal of this research was to better understand this mechanism in the copper-tolerant decay fungus *Fibroporia radiculosa*.

The decay of untreated and copper-treated wood, and the amount of copper removed from copper-treated wood, were evaluated for two copper-tolerant fungi and one copper-sensitive fungus. The two copper-tolerant fungi were able to cause higher decay and removed greater amounts of copper in copper-treated wood. Additionally, genes that could be contributing to copper-tolerance were evaluated during fungal decay of copper-treated wood. Two genes that respond to stressful environments, and two other genes that may be involved in moving copper inside the fungus, were studied.

All four genes decreased in the copper-tolerant fungi on copper-treated wood, while the copper movement genes increased in the copper-sensitive fungus on copper-treated wood. Results suggest that copper-tolerant fungi decay copper-treated wood using different genes than the copper-sensitive fungus. Future research is ongoing to clarify how copper-tolerant brown-rot fungi manage intracellular toxic copper environments.

The XyloPhone smartphone peripheral brings AI wood identification potential to your pocket

One rate-limiting factor in the fight against illegal logging is the lack of powerful, affordable, scalable wood identification tools for field screening. Computer-vision wood identification using smartphones fitted with customized imaging peripherals offers a potential solution, but to date such peripherals suffer from one or more weaknesses: low image quality, lack of lighting control, uncontrolled magnification, unknown distortion and spherical aberration, and/or no access to or publication of the system design.

To address cost, optical concerns, and open access to designs and parameters, Forest Service scientists developed the XyloPhone, a 3D-printed, research-quality macroscopic imaging attachment adaptable to virtually any smartphone. It provides a fixed focal distance, exclusion of ambient light, selection of visible light or UV illumination, and uses the lens from a commercially available loupe. The XyloPhone is powered by a rechargeable external battery, is fully open-sourced, and at a price point of less than $110, is a highly affordable tool for the laboratory or the field. It can also serve as the foundational hardware for a scalable, field-deployable computer-vision wood identification system.

Forensic Identification of CITES Appendix I Cupressaceae

Two closely-related species of the cypress family, *Fitzroya cupressoides* and *Pilgerodendron uviferum*, are endemic to southern Chile and Argentina. Both are listed in Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES), which bans them from international trade without special permits. Despite these bans, the continued loss of these trees has been difficult to curtail. Combatting such illegal logging is important to protect biodiversity through sustainable harvesting, promote economic development, curtail international crime and its attendant money laundering, and eliminate market distortion that reduces the profitability of legally traded timber. In response, the United States and other countries have enacted laws that prohibit the import or trade of illegal timber. An important aspect for stopping this illegal trade is to have effective and rapid tools for identifying the species of suspected banned timber. A collaborative project between Chile and the United States was designed to determine the usefulness of chemical and wood anatomical characteristics to reliably separate these species. Wood anatomy alone cannot separate them, but mass spectrometry was able to unequivocally determine taxonomic source. The mass spectra results obtained from

heartwood demonstrated that identification is feasible after a few seconds, using only a small sliver of wood.

Rethinking the role of water when preparing composites of micro-/nanocellulose and polymers

Cellulose micro-/nanomaterials (CNs) are an emerging class of materials with many potential applications, often in combination with polymers. Unfortunately, their preparation typically results in dilute, aqueous suspensions, and inefficient water removal prior to composite preparation has hindered commercialization. However, water may present opportunities for improving overall process efficiencies if its potential is better understood and if it is better managed throughout the various stages of CN and composite production.

Forest Service scientists and partners are seeking to better integrate water into composite preparation processes, leveraging water's ability to: (1) aid in CN dispersion; (2) act as a transport medium for metering and feeding of CNs; (3) plasticize polymers; and (4) facilitate fibrillation of pulps during composite preparation.

The perception that water has no value in polymer processing and must always be removed prior to composite preparation needs to be revisited. A more sophisticated understanding of water's role will become increasingly important as more bio-based materials are used in polymer composites.

Using synchrotron techniques to understand the role of metals in wood decay

Brown-rot fungi cause a type of wood decay that results in rapid strength loss of wood in the built environment. Research has shown that brown-rot fungi are responsible for 85 percent of the damage to

wood structures caused by decay fungi. Understanding brown-rot decay mechanisms is important because brown-rot decay can cause rapid reductions in the strength of lignocellulosic polymers even with low amounts of mass loss. It is generally accepted that the first stage of brown-rot decay involves chelator-mediated Fenton catalytic degradation where metal ions are used to generate hydroxyl radicals that depolymerize wood. However, the oxidation states of these metal ions have not been characterized during the decay process.

Forest Service scientists and partners teamed up to use synchrotron-based X-ray Absorption Near Edge Spectroscopy (XANES) to characterize the metal oxidation states during wood decay.

Investigations of fungal wood decay mechanisms reveal novel enzymes

Wood extractives, solvent-soluble fractions of woody biomass, impede or exclude fungal colonization of the freshly harvested conifers. However, certain fungi have evolved unique systems to rapidly colonize softwood stumps and thereby prevent invasive growth of destructive pathogens. To clarify the mechanism(s) of this process, an international team of scientists examined the transcriptome, proteome, and metabolome of *Phlebiopsis gigantea* when grown on defined media containing loblolly pine sapwood extractives. An array of enzymes was implicated in the metabolism of softwood. Based on its extracellular location and characterization of the recombinant enzyme, a highly expressed and inducible lipase is likely responsible for lipophilic extractive degradation. Our results provide a framework for genetic improvements of root rot biocontrol agents, and the lipase has considerable potential in a wide range of industrial processes.

Characterizing mold susceptibility

The U.S. Department of Defense utilizes a diversity of wood materials and available wood species for construction of munitions wood packaging materials (WPMs). Concerns related to mold contamination in WPMs exposed to moisture during storage or transport has necessitated the evaluation of potential moldicides that could be used with the preservative treatment systems already in use. During preliminary tests, it became clear that evaluations of moldicidal additives would be difficult because of variation in mold susceptibility across all the different wood species and wood types that are allowed for WPM fabrication. A study was initiated to examine mold susceptibility of various wood species and types, with the goal of selecting representative materials that could be used in subsequent laboratory mold tests.

Acid hydrotropic fractionation (AHF) for sustainable biorefinery

Fractionation of lignocellulosic biomass is the prerequisite step for producing fibers/cellulose nanomaterials, sugar/biofuel, biochemicals, through the biorefinery concept. While alkaline chemical pulping has been commercialized for producing commercial wood fibers, efficient and sustainable utilization of low-grade lignocellulosic biomass requires low-cost and sustainable fractionation process that remains a challenge. In this research, we are developing aqueous maleic acid hydrotropic fractionation (MAHF) to achieve efficient fractionation of lignocelluloses at atmospheric pressure. There are several advantages of maleic acid hydrotropic fractionation (MAHF): (1) maleic acid is a solid acid that can be easily recycled. Furthermore, it is an U.S. FDA-approved indirect food additive with negligible environmental impact. (2) Dissolved lignin can be easily separated through diluting the spent liquor to the minimal hydrotropic concentration with water. (3) Both the dissolved lignin are minimally

condensed and carboxylated that facilitate valorization. Furthermore, the residual lignin is also carboxylated that improved enzymatic sugar production at low cellulase loadings, mechanical refining and fibrillation for fiber and cellulose nanomaterial production from the fractionated solids; (4) The dissolved xylose can be dehydrated into furfural by the maleic acid in the spent liquor without additional catalyst. These advantages were demonstrated in the publications that include an invited minireview on the subject featured on the cover of the August issue of ChemSusChem.

Sustainable production of cellulose nanomaterials

Existing processes for producing cellulose nanomaterials (CNM) suffers from difficulties in chemical recovery or expensive mechanical energy cost using pure mechanical processing. In this research we focus on using dicarboxylic acids to produce carboxylated CNM (DCA–CNM), including CNCs with chiral nematic properties, DCA-CNFs with great dispersity, and cellulose nanowhiskers (DCA–CNWs) with similar morphology to CNCs. The less corrosiveness nature and great recyclability of solid dicarboxylic acids are substantial advantages over mineral acid hydrolysis for producing conventional sulfuric acid CNCs. The DCA–CNM also has higher thermal stability than sulfuric acid CNCs. We also found that DCA–CNF performed better in water-based oil drill fluids than commercial product. We also developed reaction kinetics for tailored production of a diverse of DCA–CNM with desired morphology. When using maleic acid, an acid hydrotrope, we can produce LCNM directly from raw biomass through MAHF process. Recent progress are reported in the listed publications including a perspective paper in Nature.

X-ray crystallographic protein structure determination of the novel bacterial xylobiohydrolase AcXbh30A

The novel bacterial xylobiohydrolase, derived from *Acetivibrio clariflavus*, AcXbh30A, has been shown to be highly specific in the hydrolysis of xylan to yield xylobiose. Xylobiose is a prebiotic dimeric sugar derived from lignocellulosic biomass and a major functional food ingredient. Inclusion of the enzyme xylobiohydrolase in multi-enzyme systems can be used to generate novel structured, branched xylooligosaccharides and xylobiose.

As part of continued research into the function of this enzyme, Forest Service scientists and partners have obtained protein crystal structure models of AcXbh30A using X-ray crystallography. The xylobiose bound structure reveals why this unique xylobiohydrolase shows better specificity then similar fungal-derived xylobiohydrolases. The xylobiose is complexed into a 2-sugar-sized binding slot and makes four specific hydrogen bond contacts.

Understanding the crystallinity and supramolecular structure of cellulose

Crystallinity and structure of aggregated cellulose are poorly understood, and the current methods used to measure these qualities have limitations. Therefore, further investigation was carried out in this study, using cotton microcrystalline cellulose (MCC) and ball-milled MCC. It was found that when these ball-milled samples were wet with water, most underwent conformational changes at the molecular level. Although formation of cellulose II (another type of cellulose whose crystal structure differs from that of cellulose I) was observed in longer duration than ball-milled samples, the changes primarily gave rise to

increased contributions in spectral and diffraction regions typically associated with the contributions of crystalline cellulose I.

Moreover, when the wet samples were air-dried at 25 °C, the newly formed cellulose I-like structures partly reverted to the previous form present in the initial dry state. These findings explained for previously studied X-ray diffraction and nuclear magnetic resonance observations, where the addition of water resulted in increased crystallinities of cellulose samples.

Characterizing nanocelluloses to comprehend their application potential

To optimize the applications of cellulose nanocrystals (CNCs), it is important to understand their supramolecular structures. In this research, using many techniques, structures of sulfuric-acid-produced CNCs were analyzed. CNCs were produced from poplar wood, bleached kraft pulp, cotton microcrystalline cellulose, bacterial cellulose, tunicin, and cladophora cellulose. The findings indicated that significant differences among the CNCs existed, and that they seem to arise largely from differences between the starting materials. This research helped in estimating the applications of the various types of CNCs.

Hitting the reset button on water vapor sorption in wood

The uptake, or sorption, of water vapor is a fundamental characteristic of wood. Moisture content affects most engineering properties of wood, including heat capacity, thermal conductivity, strength, stiffness, and dimensions. Furthermore, moisture is vital for wood degradation mechanisms such as fungal decay. The basic physical interaction of water vapor with wood at the molecular level has long been interpreted using theoretical models that were developed for other materials. Although these idealized systems are

inconsistent with wood-water interactions and ignore important physical phenomena, the sorption models happen to provide acceptable empirical fits to the relationship between equilibrium moisture content and relative humidity. The models have also been widely used in the wood science literature to predict physical properties of wood.

To test the validity of common sorption models, Forest Service scientists and partners first identified the most reliable literature data for water vapor sorption in wood over a wide range of temperatures. They then fit the models to the sorption data and evaluated physical properties predicted by the models against independently measured values. They found that none of the theoretical models accurately predicted any of the physical properties. They conclude that these models are not valid. To move wood science forward, new models are needed that correctly describe wood-water interactions.

Better enzyme cocktails for biorefineries

Fungi are experts at eating lignocellulosic biomass, i.e., wood. Biomass has three major biopolymers: cellulose, hemicellulose, and lignin. By producing a mixture of enzymes, they break these biopolymers into bite-sized pieces. For example, cellulases break cellulose down into simple sugars. Fungi adapt the quantity and type of enzymes for the biomass they are consuming.

For many years, there has been a desire to use fungal enzymes on an industrial scale. Forest Service scientists and partners aimed to turn woody biomass into simple sugars, so these sugars can be fermented into biofuels and other products. Typically, the enzyme supplier grows the fungus, isolates the enzymes, blends several types of enzymes, and ships them to the biorefinery. Enzyme cost is often the second highest operating cost, after biomass cost. In this study, Forest Service scientists and partners

show that by letting fungus grow on the substrate, it produces an enzyme cocktail as good as a state-of-the-art commercial enzyme mixture. This opens the door to producing optimizedenzymes onsite at a biorefinery, which would reduce cost and improve efficiency.

Digging deeper into the science, this study also gives guidance to enzyme producers. The study combines complete biomass characterization, observations of fungal morphology, measurements of enzyme activity, and genomics. Fungus grew on softwood samples that were pretreated in three different ways: one pretreatment removed most of the lignin; one removed most of the hemicellulose; and one opened the structure, but largely did not change the composition. By acquiring data from several scientific disciplines on fungi grown on systematically varied substrates, it is possible to identify fiber characteristics that correlate with the expression of each class of enzymes. As expected, the greatest variation was observed for the hemicellulose-specific enzymes, xylanases and mannanases.

Estimating lumber properties with acoustic-based technologies

In this research article, Forest Service scientists and partners used fundamental mechanics in an idealized specimen to derive a mathematical model of acoustic wave behavior. Published information on the physical and mechanical properties of clear, defect-free wood are inputs in the model to examine acoustic wave behavior. Wave behavior is then examined experimentally in a series of wood specimens. Observed wave behavior in the clear wood specimens, in both time and frequency domains, closely resembles idealized wave behavior. The predictions from the model are used to improve estimation of the ultimate tension stress of wood specimens.

Southern Yellow Pine Properties across Five Decades

Climate change, forest management, genetics, processing, and other factors have been considered as reasons for the change in design values of southern yellow pine, which occurred in 2012. Whether the mechanical properties of this resource have changed over the past 50 years remains an open question. This research uses archival and modern data to detect possible resource changes in southern yellow pine density, flexural properties, compression properties, stiffness, and strength.

The use of ground-penetrating radar in the evaluation of wood structures

Moisture detection is of prime concern in wood products, and several researchers have labored to measure internal moisture using ground penetrating radar (GPR). While there have been several laboratory studies involving the use of GPR on wood, its use as an inspection tool on large wood structures has been limited. Knowledge gaps have been identified that need to be addressed to improve the efficacy of GPR as a reliable inspection tool of wood structure. Chief among these gaps is the ability to distinguish the type of internal feature from GPR output, and the ability to identify internal decay.

A convenient and inexpensive bioreactor for oxidation of wood sugars

There is great potential for the manufacture of high-value chemicals from wood sugars using a combination of chemical and biological catalysts. To demonstrate the utility of an inexpensive inflatable shipping pillow as a reactor for bio-catalysis, Forest Service scientists and partners oxidized glucose on a multigram scale using an enzyme derived from a wood-decay fungus that was expressed at high levels in a bacterium. Importantly, only a single charge of 100 percent oxygen is required for stoichiometric conversion of glucose using the shipping pillow bioreactor with a high surface area at the liquid-gas interphase and with gentle mechanical mixing for whole-cell catalysis. The reaction can be successfully

repeated with recycled bacterial cells that are easily recovered by centrifugation. The resealable valve of the shipping pillow is a convenient port for transfer of both the reaction solution and molecular oxygen. In contrast to rigid-walled reactors, the sealed inflatable/collapsible pillows maintain constant pressure (1 atmosphere) of 100 percent oxygen even as the gas is consumed. This method is expected to have application with other oxygen-dependent enzymes.

Cradle-to-grave life-cycle assessment and techno-economic analysis of biochar produced from forest residues with various portable systems

Producing biochar from forest residues can help resolve environmental issues by improving soil quality, which can reduce the impacts of forest fires and climate change. However, transportation and storage of biomass to a centralized facility is often cost-prohibitive and a major hurdle for the economic feasibility of producing bio-based products, including biochar. This study evaluates the environmental impacts and economic feasibility of manufacturing biochar from forest residues with small-scale portable production systems such as Biochar Solutions Incorporated (BSI), Oregon Kiln (OK), and Air Curtain Burner (ACB).

The results illustrated that the global warming impact, as measured by carbon sequestration, of biochar production through BSI, OK, and ACB were 0.25–1.0, 0.55, and 0.61-tonne CO_2eq./tonne biochar applied to the field, respectively. One tonne of biochar, produced with the portable system at a near-forest site and applied to the field, reduced the global warming impact by 0.89–2.6 tonnes CO_2eq. Overall, the net global warming impact of biochar produced from forest residues can reduce environmental impacts (i.e., 1–10 times lower CO_2eq. emissions) compared with slash-pile burning. The MSP per tonne of biochar produced through BSI, OK, and ACB were $3,000; $5,000; $1,600; and $580,

respectively, considering 100 working days per year. However, with improved BSI systems, when allowed to operate throughout the year, the MSP can be reduced to below $1000/tonne of biochar. Further, considering current Government grants and subsidies (i.e., $12,600/ha for making biochar production from forest residues), the MSP of biochar can be reduced substantially (30–387 percent) depending on the type of portable system used.

The portable small-scale production systems could be environmentally beneficial and economically feasible options to make biochar from forest residues at competitive prices, given current Government incentives in the United States, where excess forest biomass and forest residues left in the forest increase hazard to wildfire.

Mechanical performance of hybrid CLT panels made of low-value sugar maple and white spruce

Tall timber buildings have gained more and more attention in North America. Massive composite timbers such as cross-laminated timber (CLT) are essential for tall timber buildings that require use of locally available wood resources to reduce manufacturing costs and minimize environmental impacts. This opens a potential sustainable market for undervalued hardwoods dominating the Lake States and the Northeastern United States. Current commercial CLT building products are almost exclusively made from softwood species, primarily spruce and fir. Although those softwood CLTs generally can meet code requirements, they have some deficiencies inherent from the material from which they are made. For example, the low rolling shear strength is due to low stiffness and strength properties of softwoods.

This study evaluates the mechanical performance of hybrid mixed species CLT panels made of low-value sugar maple and white spruce boards through a mechanical test and numerical simulations. Three-

layer hybrid CLT panels with layup combinations of sugar maple-white spruce-sugar maple and white spruce-sugar maple-white spruce were prepared to evaluate the effects of layups on the performance of the CLT samples. The mechanical properties of hybrid CLT panels were evaluated with different layups and both melamine- and resorcinol-based adhesives. The influence of adhesive types was not significant. The mechanical properties of the hybrid CLT panels with sugar maple surface layers were improved significantly compared with those of the current standard layups.

The results of this study suggest that the hybrid CLT with low-value sugar maple and white spruce can provide better structural performance than standard CLT made with spruce-pine-fir. Enhancing the panel properties by using low-value sugar maple lumber in individual layers is feasible and effective.

Influence of temperature on termite gut microbiome

Temperature is a major factor influencing insect distribution because insects cannot regulate their own body temperature. Instead, their internal temperature fluctuates with external environmental conditions. To survive, insects must adapt both physiologically and behaviorally to contend with shifting climate conditions. Recent work has suggested that associations with symbiotic microorganisms may help foster tolerance to thermal stress.

Subterranean termites are widely distributed across the United States but are limited by harsh winter conditions along their northern range. While several researchers have examined certain physiological responses in termites to varying temperatures, little attention has been given to the impact of temperature on termite gut symbionts. Microbial symbionts in termites have been credited as drivers of species evolution in termites, so there is strong potential for these symbionts to impart some level of thermal

tolerance plasticity. Forest Service scientists and partners examine the response of termite bacterial symbionts to temperature stress. Results showed distinct shifts in termite gut microbiota with temperature exposure that may be related to cold tolerance. This research advances understanding of the potential links between microbial symbionts and adaptability. This type of work is important for future predictions of termite dispersal and establishment, particularly in colder, temperate climates where termite risk is generally considered to be lower.

Mechanical performance of CLT panels made from salvaged beetle-killed white spruce

Dead standing trees resulting from insect outbreaks increase the hazard to wildfire and pose a safety hazard in recreation areas. Forests left in the wake of an insect outbreak represent a significant economic resource. Timber salvage from such areas could generate revenues for affected landowners to offset the cost of forestland restoration. Manufacturing cross-laminated timber (CLT) with nondestructive rated salvaged lumber could be a high value-added option for utilizing the salvaged lumber. The orthogonal layup of CLT can reduce the impact of mechanical property variance caused by local defects such as checks, knots, and decay by redistributing the loads into other directions.

This study evaluates the flexural and shear properties of CLT panels fabricated from salvaged dead standing white spruce resulting from recent eastern spruce budworm activity in Upper Peninsula, Michigan, through mechanical tests and computational analysis to determine whether the CLT panels can reach the standards required by the PRG 320 standard. The results suggest that CLT panels fabricated from salvaged white spruce can meet the baseline performance requirement of the PRG 320 standard and provide adequate stiffness and strength for uses as structural components, especially for components under bending with short spans. The finite element modeling of the CLT panels, according

to the orthogonal constitutive law and progressive damage model, can be used to estimate the flexural and shear properties of CLT panels, based on the lamination E-rating results. A comprehensive qualification testing program is recommended to further validate the use of salvaged white spruce lumber in manufacturing CLT panels.

Cellulose nanomaterials from wood have the potential to improve the shelf-life of dry food in bio-based packaging

The potential of neat bio-based polyactic acid (PLA) and PLA/cellulose nanocrystal (CNC)-blown films in extending the shelf-life of crackers, a moisture-sensitive food product, was assessed. The shelf-life of the crackers, defined as the time required by the product to reach its critical moisture content (CMC) of 8 percent, was determined experimentally from moisture content versus storage time plots at a constant temperature (25 °C) and various conditions of relative humidity. Neither crackers within PLA nor PLA/CNC packages reached the CMC when stored below 50 percent relative humidity at 25 °C, indicating that crackers packaged in both films were shelf-stable at these conditions. Above this relative humidity, the crackers inside both packages reached the CMC at different times; however, crackers in CNC-based packages had approximately 40-percent longer shelf-life than those in neat PLA packages.

Wildland fire may be more sensitive than we think

Wildland fires occupy the biosphere as both an ecological process essential for maintaining species diversity and a hazard to human lives, infrastructure, and activities. Our ability to anticipate fire behavior is key to maximizing ecological value of fire while simultaneously minimizing negative impacts. Predictive models are often called upon as tools to aid in forecasting potential outcomes.

However, prediction of fire behavior is complicated by the fact that small changes in environmental conditions can have large impacts on wildfire outcomes. This is most evident in marginal burning conditions, like prescribed fire, where fine-scale details have been observed to drastically influence resulting fire behavior. FPL scientist Kara Yedinak, along with colleagues from Los Alamos National Laboratory, have begun quantifying the sensitivities of wildfire behavior to small changes in atmospheric conditions using FIRETEC, a process-based, computational fluid dynamics model of fire-atmosphere interactions.

Repeat (ensemble) simulations are used to sample small changes in the turbulent wind field over evenly distributed grass. Characteristics of the turbulent atmosphere are probed to better understand mechanisms that may influence fire behavior. Overall spread is quantified using a variety of metrics to look for clustering and diverging behaviors. The results indicate a sensitivity to perturbations that show less predictability as the burning conditions grow more marginal.

Soft-story seismic isolation with elliptically profiled CLT

Curvilinear cuts to CLT panels and steel connections transform the wall system into a form of soft-story isolation that may buffer buildings from sustaining damage, even in major earthquakes.

Cross-Laminated Timber shear wall seismic force resisting system in U.S. codes

Cross-Laminated Timber (CLT) offers several advantages to the wood building market, such as the potential for mass production, prefabrication, construction speed, 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 required attention was the development of a CLT lateral shear wall system that can be used in seismic and high-wind regions of the United States. CLT shear wall-based Seismic Force Resisting Systems (SFRS) are not recognized in current U.S. design codes.

A 5-year systematic research effort integrated a suite of CLT building archetypes, a new design methodology, both component and systems tests, nonlinear static and dynamic structural modeling, and incremental time history analyses and incorporated uncertainties. All phases of development resulted in both the structural design procedure and associated seismic design parameters that led to a code changes proposal at the Building Seismic Safety Council (BSSC), American Wood Council (AWC), and American Society of Civil Engineers (ASCE).

Performance of structural insulated panel walls under seismic loading

Structural insulated panels (SIPs) are strong and energy-efficient construction systems that use the strength of wood structural panels and the energy attributes of foam plastic insulation to provide cost-effective solutions for compliance with governing building codes. However, the acceptance of SIPs by many design professionals has been hindered by the lack of a systematic evaluation of their lateral load performance in wall applications.

This research established the test data needed to characterize the lateral load performance of SIP walls with full bearing on a sill plate and a cap plate (restrained) under cyclic loading. The program involved structural testing of 54 full-sized SIP walls of various configurations that bracketed a range of SIP wall

configurations commonly used in the field. Single-wall configurations were evaluated with and without hold-downs.For broad acceptance of SIPs in high seismic regions, hysteric models are critical for nonlinear time history analysis. Data generated in this study was used to determine the 10 parameters for the modified Stewart models.

Based on experiments of SIP wall configurations with openings, it is justified for engineers to use the traditional Perforated Shear Wall approach to predict stiffness and strength of these wall arrangements. Finally, lateral load resistance of single-panel SIP walls with aspect ratios of 1:1, 2:1, and 3:1, and five-panel SIP walls without openings, satisfied the cyclic performance parameters of overstrength, drift, and ductility capacities, as defined in ICC–ES acceptance criteria AC04 and ASTM D7989, which is equivalent to light-frame walls. This analysis has been presented and is currently under review by the ICC–ES staff for acceptance.

Determining char rates of exposed glulam columns to a 3-hour standard fire

The fire resistance of a structural building member consists of its ability to survive a specified fire, in both exposure and duration, without loss of its loadbearing function. For exposed mass timber, the ability to endure a fire includes the development of a char layer that protects the unburned wood. The rate at which the char layer forms as the thermal wave moves deeper into the wood is known as the char rate. Char rates are then used to calculate the residual load-bearing cross section to appropriately size wood structural members. The current calculation method relies on an empirically derived char rate of 1.5 inches/hour, which was obtained from numerous standard fire tests and has only been verified for fire resistance ratings of 2 hours or less.

Currently, mass timber structural members are required to be protected with layers of noncombustible fire protection, such as gypsum board, to achieve a 3-hour fire resistance rating required in highrise buildings. However, over the past decade there has been a push toward greener buildings utilizing mass timber elements and a desire by designers to leave the wood exposed rather than covering it with noncombustible protection. To achieve this, the char rates of glue-laminated timber to use in the fire resistance calculations of up to 3 hours were needed.

Forest Service scientists and partners exposed nine glue-laminated columns to the standard fire for 3 hours in an intermediate-scale furnace. Three types of columns were tested in triplicate, all without noncombustible protection. The columns were highly instrumented with thermocouples to obtain the thermal profile during the exposure period. Both the temperature profiles and the final cross-sections used calculated a char rate for glulam at 3 hours. The fire test results provide a verified char rate needed to calculate the amount of outer sacrificial char layer to obtain a 3-hour rating. This can be used to inform engineering analyses of exposed mass timber in highrise mass timber structures, further increasing the adoption of mass timber in the United States.

United States Forest Products Annual Market Review and Prospects, 2015–2021

In 2020, the United States began on firm economic footing, but by June, COVID-19's effects on world health, and U.S. and world economies, were becoming apparent. The FOMC revised their 2020 U.S. GDP forecast to −3.7 percent and the FRBP-SPF projected it at −5.2 percent. COVID-19's negative effects on employment were greater than those from the Great Recession.

U.S housing markets continued their steady, but gradual, recovery in 2019 and into 2020. In spite of COVID-19's devastating effects, new housing construction is a bright spot for the U.S. economy. In the first half of 2020, total starts were 2.3 percent greater and single-family starts were minimally less (0.3 percent) than reported for the same period in 2019. New house sales in 2020's first half were nearly 690,000 units and this was 2.8 percent more than the first half of 2019. R&R's expenditure volume surprised most and improved more than 15 percent from 2019's first half. The shelter-in-place or work-at-home orders resulted in a positive effect on the R&R subsector and may lead to changes in residential design and nonresidential construction.

The shelter- or work-at-home orders are a double-edged sword—consumer paper products recorded large purchase increases, while office paper products were the opposite. In 2019, several wood product categories production and consumption volumes were negligibly less than in 2018— other categories reported moderate declines. Softwood lumber production and consumption both increased year-over-year in 2019. Composite panel products; hardwood plywood; and furniture consumption also increased from 2017 to 2018. Wood pellet production and sales continue to increase. One factor for the increase is that several Euro nations have invested substantially in pellet facilities for the generation of electricity. Conversely, sawn hardwood production and consumption decreased for the second consecutive year; structural panel production and consumption was minimally less than 2018; paper and paperboard production remain in a decade long decline; pulpwood consumption decreased for the fifth year in a row; and furniture production declined from 2018 to 2019. Softwood lumber exports decreased in 2019, due to trade tensions, decreasing demand, and a surge in Central European exports.

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 decision making. Although a number of Forest Service tools have been developed, IT modernization and cybersecurity needs require tools to be checked by the Chief Information Office to receive approval to be used on USDA-imaged computers. Major decision support tools include:

- LANDIS II 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. Hosted by partners; (https://www.landis-ii.org/)

- 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. App hosted by partners; https://apps.bugwood.org/apps/southern-forests/

- i-Tree - i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefits assessment tools. The i-Tree tools can help

strengthen forest management and advocacy efforts by quantifying forest structure and the environmental benefits that trees provide. Since the initial release of the i-Tree tools in August 2006, thousands of communities, nonprofit organizations, consultants, volunteers, and students around the world have used i-Tree to report on individual trees, parcels, neighborhoods, cities, and even entire States. By understanding the local ecosystem services that trees provide, i-Tree users can link forest management activities with environmental quality and community livability. Whether your interest is a single tree or an entire forest, i-Tree provides data that you can use to demonstrate value and set priorities for more effective decision-making. Hosted by partners; https://www.itreetools.org/

• 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. (https://www.fs.usda.gov/pnw/tools/ecosystem-management-decision-support-emds-system)

• FireFamilyPlus (FF+) - is a software package used to calculate fuel moistures and indices from the U.S. National Fire Danger Rating System (NFDRS) using hourly or daily fire weather observations primarily from Remote Automated Weather Stations (RAWS). NFDRS use is mandated for fire preparedness and response decisions by all Federal and most State agencies and is operationally run

with USFS FAM Weather Information Management System (WIMS).

(https://www.firelab.org/project/firefamilyplus)

• Forest Vegetation Simulator (FVS) - Forest Vegetation Simulator (FVS) is a family of forest growth simulation models. https://www.fs.fed.us/fvs/

• The Hot-Dry-Windy Index improves fire weather forecasting - A new tool helps fire managers anticipate when wildfires could become erratic or dangerous. Hosted by partners; https://www.hdwindex.org/

Data – Forest Service Research Data Archive (FSRDA)

The FSRDA was created in 2010 to publish and preserve digital scientific data collected from studies funded by Forest Service R&D and the interagency Aldo Leopold Wilderness Research Institute. In 2012, its scope expanded to the interagency Joint Fire Science Program (JFSP). To date, ~25 percent of FSRDA publications are from JFSP-funded studies. In 2019, a pilot project was initiated to provide publishing support for USDA APHIS' National Wildlife Research Center. FSRDA actively works with the network of Forest Service Experimental Forests, Ranges, and Watersheds 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 118 new data publications in FY 2021. Data publication downloads increased 32 percent relative to FY 2020. This is the 10th consecutive year of substantive increases in the customer base. Interest in western wildfires was reflected in strong interest in FSRDA data publications describing

wildfire occurrence, wildfire hazard potential, and wildfire risk to communities. 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 NFS users via the Forest Service Enterprise Data Warehouse. 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 (e.g., the State of New Mexico's website presents fire data from one of the FSRDA publications).

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 United States 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 Forest Inventory and Analysis program, promotes the development of policies that support the conservation and wise management of public and private forests.
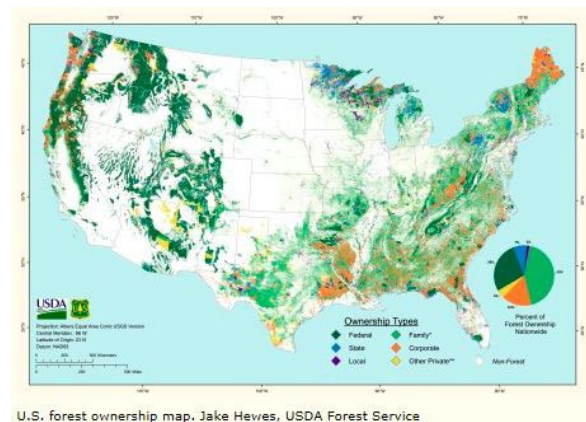
More than half the forest land in the United States is owned and managed by some 11 million private forest owners. These working forests benefit us all. Private forest lands:

- supply nearly 30 percent of the water we drink as well as provide clean air, fish and wildlife habitat, and significant recreation opportunities;

- provide over 90 percent of our domestically produced forest products, including the timber needed to build homes and fuel wood for heating them;

- support 2.4 million jobs primarily in rural communities; and

- contribute to our Nation's energy security, housing, and infrastructure.

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 nonforest uses. S&PF 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.

Tribal Relations

The Tribal Connections Viewer is a new geographic information systems tool available to Forest Service staff, Tribes, and others that provides a visual, interactive map that shows where and how lands managed by the Forest Service connect or overlap with current Tribal trust lands. Nearly 4,000 miles of

shared boundaries between Tribal lands and Forest Service-administered/owned land are identified. Tribes and the Forest Service can now engage in shared land management activities across administrative boundaries and at larger landscape scales than was previously possible. This online resource helps to promote sound management of protected areas through conservation efforts, capacity-building activities, and education initiatives. 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.

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 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 Forest Service; or collaboration on conservation projects and programs. 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. Housing this information in one, easily available online resource will improve the efficiency of Forest Service-Tribal coordination, collaboration, and consultation.

Wildland Fire

Wildfire season is now year-round and, regardless of where they start, wildfires impact thousands of communities at the wildland-urban interface. 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. Some examples are:

Community Fire Adaptation – Federal, State, and local governments partner with nonprofits, fire departments, and other stakeholders to reduce wildfire risk locally through 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, supported by experience on the ground, and shared with communities and partners nationwide.

Wildland-Urban Interface Research – Work to reduce community wildfire risk by the Forest Service and its partners is based on science and verified by experience. Partners like the JFSP, the Insurance Institute for Business and Home Safety, the various Forest Service Research Stations, and Forest Service fire scientists 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 this 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 the 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.

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, the Forest Service continues to increase technology transfer through important partnerships with career and volunteer fire departments nationwide. Worked with the National Volunteer Fire Council to help share best practices for assessing homes and communities for wildfire risk and ways to share that information with residents.

The FAC Learning Network – out of which grew 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 the FAC Learning Network 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.

The Fire Adapted Communities Coalition was formed in 2009 and still functions primarily as a technology transfer, information sharing effort among partners (and their individual audiences) engaged in community wildfire mitigation efforts. Coalition partners share their successes and the work they are doing to help communities reduce risk, and work to collaborate for efficiency 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. Fire Adapted Communities Coalition members are the 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, 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 works 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. Within FHP, the Forest Health 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. FHP conducts aerial surveys and uses remote sensing to assist Federal and State partners and the public, and to guide forest management actions to improve forest health. The FHP program also uses data from ground plots and surveys, and other biotic and abiotic data sources, and develops analytical approaches to address forest health issues that affect the sustainability of forest ecosystems. These efforts make scientific data available to land managers and States to reduce the risk and impact of damage caused by insects and diseases.

FHP recently completed a 2018 update of the National Insect and Disease Risk Map (NIDRM) and has facilitated transfer of these digital data to States in support of the 2020 State Forest Action Plan updates. The NIDRM provides a nationwide strategic assessment of the risk of tree mortality caused by 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; or

- in the Eastern United States only, 3 or more consecutive years of defoliation mapped by aerial detection surveys.

The 2018 update does not account for increases in risk due to recent tree growth and increased density, which can render 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 aerial detection survey data to future projections of mortality events associated with forest pests.

- 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 communication and awareness of forest health threats.

Urban & Community Forestry

The Forest Service is a proud partner in restoring and sustaining America's community forests. The Urban & Community Forestry (UCF) Program supports forest health for all our Nation's forests, creates jobs, contributes to vibrant regional wood economies, enhances community resilience, and preserves the unique sense of place in cities and towns of all sizes. By working with State partners to deliver information, tools and financial resources, the UCF Program supports fact-based and data-driven best practices in communities—maintaining, restoring, and improving the more than 140 million acres of community forest land across the United States. Learn more about how the UCF program supports a thriving America. The Forest Service has a long history—well over three decades—of delivering urban forestry research, technology, and information to partners, stakeholders, and customers. In FY 2019, the UCF Program provided technical or financial assistance to more than 7,755 communities across the United States. Sharing Forest Service knowledge and tools is essential to improving the management and long-term sustainability of urban ecosystems. 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 Forest Service to continue providing much-needed science and technology delivery services. This demand is increasing as the 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 customers, the Forest Service formed the UCF Technology and Science Delivery Team in 2014. This team is made up of S&PF UCF Program Managers and Forest Service R&D personnel from around the country. The group's focus is on ensuring Forest Service urban forestry staffs are strategic, skillful, creative, and nimble in our science delivery efforts. The team employs a contemporary technology transfer approach to reach 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.

Priorities, tasks, resource allocation, partnerships, program direction, performance measures, and accountability at all levels of the UCF Program align with the seven goals outlined in the collaboratively developed Ten-Year Urban Forestry Action Plan (2016-2026):

1. Planning

2. Human Health

3. Diversity, Equity and Leadership

4. Environmental Health

5. Management

6. Funding

7. Education and Awareness

Important new UCF-supported resarch includes:

Trees Cool Cities and Save Human Lives

Heat-related deaths are a major concern as more frequent and severe heat waves threaten U.S. cities. Forest Service scientists worked with external partners to develop a tool that calculates how much tree cover can help. The team estimates 3,800 fewer deaths in New York City with a 10-percent increase in tree cover! This tool will be essential for urban planners in efforts to mitigate climate change and promote environmental justice and equity. This work also builds on a previous study that found tree canopy cover could mitigate premature heat-related deaths in Philadelphia.

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, the Forest Service is 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 a 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. WoodWorks provides technical expertise on a wide range of building types, including schools, mid-rise/multifamily, commercial, corporate, franchise, retail, public, institutional, and more. The $2 million contributed by the Forest Service in 2017 leveraged an additional $4.5 million from the wood industry and the Canadian government, allowing significantly greater impact than could have been achieved independently. 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. WoodWorks has directly or indirectly influenced the use of wood in over 500 buildings.

Owner Assistance

The Forest Service cooperates with researchers and partners to understand landowner behavior and develop technical assistance programs that meet the interests and management needs of America's nonindustrial 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, S&PF 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, the Native Plant Propagation Protocol database, *Tree Planters' Notes* (international applied journal focused on plant production and establishment), and a website with over 70,000 downloads annually of articles pertaining to reforestation, restoration, and native plant production.

The Forest Legacy, Community Forests and Open Space, Landscape Scale Restoration, and Forest Stewardship 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, nonprofit organizations, and university extension programs. The Forest Legacy program has online implementation tools and is developing a resource library for States and other partners. The Forest Legacy Program 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, the Forest Stewardship Program, 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 nonprofit 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 management actions 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 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 decisions. Forest Service Conservation Education is part of the advisory board of the Conservation Education Works project, developed by the North American Association for Environmental Education and Stanford University, which is designed to demonstrate the impact and value of environmental education by substantiating powerful anecdotes from across the professional 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 researchers, educators, and land users.

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 on STEM education, targeting 5th–8th grade students. Hardcopy and digital publications are available to students and educators. These publications educate students about research generated by the Forest Service, engage youth in STEM education, and inspire youth to pursue science-driven careers. Scientist cards present information on specific Forest Service 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 Forest Service reaches underserved children and their families through healthcare providers with prescriptions to recreate in parks and forests near their homes with an emphasis on underserved areas of the country. Over 880 healthcare 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 Forest Service lands has been estimated at $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. Recent important technical transfer examples include:

- 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 equivalent to 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 region'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 rainwater 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 removing dissolved substances, thereby impacting water quality. 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 used to protect water quality from the diverse range of ground disturbing and management activities that occur on national forest system lands. The national best

management practices monitoring program provides consistency for evaluating 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. 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. 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 is used by air resource advisors to model and create public smoke forecasts, compliant with S.47 Dingle Act of 2019.

Monitoring 4.1 is 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 includes updated layers and development of an analysis tool.

Fire Sciences Laboratory (list) https://www.fs.fed.us/research/wildland-fire/

7.2. Science Delivery by 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; nongovernmental 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 nonindustrial 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.

Despite the unprecedented difficult circumstances caused by the COVID-19 pandemic, hazardous conditions and poor air quality induced by a devastating wildfire season, and staff shortages due to hiring limitations, the FIA program conducted inventory activity in all 50 States, including Interior Alaska, and U.S. islands. Field plots have been collected on approximately 91 percent of the U.S. forestlands, with the remaining 9 percent in parts of Interior Alaska yet to be surveyed and only accessible by air. 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

Leads the Resources Planning Act (RPA) Assessment, conducting 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 of 1974, 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. The 2020 RPA Assessment is currently anticipated to be released by the end of 2022.

Sustainability Assessment

The Sustainability Assessment program conducts research on criteria and indicators of forest sustainability (54 indicators in total). It uses existing sources to compile data to populate specific indictors at a national aggregate level, and it uses these to provide a comprehensive picture 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. 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

IMAR staff provides advocacy of field researchers' work in remote sensing and geospatial analysis research broadly at multiple spatial scales in boreal, temperate, and tropical forest ecosystems. Research scientists serve on NASA's Landsat Science Team, coordinate the biomass estimation function of NASA's GEDI (Global Ecosystem Dynamics Investigation) mission, and serve on Carbon Monitoring System Biomass and Uncertainties Working Groups, and have been instrumental in the NASA Arctic-Boreal Vulnerability Experiment (ABoVE) programs. This area also serves as the Federal Geographic Data Committee co-lead for the land use-land cover (LULC) theme in annual reporting in response to the Geospatial Data Act (GDA) of 2018. Under the LULC Theme, 13 National Geospatial Data Assets (NGDA) are officially recognized, of which the Forest Inventory and Analysis Database is recognized as an NGDA. Other NGDAs include Landfire, National Land Cover Dataset (NLCD), NLCD-Tree Canopy Cover, and USDA NASS's Cropland Data Layer.

Some of the research is focused on increasing the Forest Inventory and Analysis program's National Forest Inventory efficiencies and meeting broader user needs. 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.

Recent achievements by IMAR staff and FIA units located at the research stations

Some of efforts to transfer the technological and research findings to the scientific community and public include:

- *Published a cost-effective field measurement [protocol](#) to support lidar-assisted carbon monitoring programs* – FIA produced a prototype of a "measurable, reportable, verifiable" (MRV) design for cost-effective carbon monitoring using a limited number of FIA field plots integrated with lidar sampling and disturbance information derived from Landsat time series data. The report documents field measurement protocols that are consistent with those of the FIA Program and can be used in combination with remote sensing data sources to estimate and model forest carbon and biomass at multiple spatial scales.

- *Developed a [tutorial](#) in model-assisted estimation with application to forest inventory* – National forest inventories in the United States. combine ground plot data with remotely-sensed information to improve precision in estimates of forest parameters. Because of the increased availability of remotely-sensed data with improved spatial, temporal, and thematic grains, there

is a need to equip the forest inventory community with a more diverse and applicable set of statistical estimators. This tutorial provides the steps on how to construct and assess the relative performance of seven estimators using forest inventory data. Related publications can be found in *Forests* 2020.

- *Published report on defining, analyzing, and understanding the U.S. Land Base* – an effort to assess the changes in U.S. forestland area depending on what definitions, methods, and datasets are used to measure.

- *Released the latest results from the FIA National Woodland Owner Survey through a new dashboard* – The new data shed light on who owns America's forests, why they own land, what they have done with it in the past, and what they plan to do with it in the future. This information can be used in designing programs and policies that help family forest owners obtain the information and assistance they need to help conserve forests for current and future generations.

- *Delivered urban FIA data through updated application, My City's Trees* – A major update to this web application improved the functionality to explore exiting and new data for inventoried cities.

- *Published report to provide a compilation and analysis of all conversion factors for roundwood and residue used by FIA in each regional Timber Product Output (TPO) program* – For the first time, conversion factors used to convert mill-reported volumes to various units of measurement in TPO data processing were made available to researchers and the general public. Access to these conversion factors will allow TPO data users to understand how reported volumes are determined.

- *Making forest inventory data ready to use through FS management tool, the Forest Vegetation Simulator* – The Forest Vegetation Simulator (FVS) is used by scientists and managers to project forest conditions into the future under a wide range of different management scenarios at scales ranging from single stands to entire States. FIA made forest inventory data available in FVS-ready format for users to have access to a consistent and accurately translated inventory dataset. The data are now being used for numerous applications, such as national forest planning, education, scientific analysis, and management of small private forest ownerships.

- *Intensified forest inventories across the Pacific Coast to inform climate analysis and policies, as well as managing forest carbon resources* – The greater intensity of plot measurements will improve forest and carbon estimation accuracy and improve estimates of carbon pool dynamics for wildfire, insects, and drought effects. As States consider carbon policy options to combat effects of a changing climate, the FIA program can help by providing unbiased estimates of current forest carbon stocks and flux.

- *Released the first inventory of the Tanana Valley in Interior Alaska* – Inventory data from the first fully-completed unit of the Interior Alaska, the Tanana Valley unit, became available online. The remote location of the 33.7-million-acre inventory unit made field data collection cost-prohibited. FIA partnered with local communities and the State of Alaska, as well as leveraging high-tech innovations developed by NASA to pilot a new way of monitoring remote areas and reduce costs.

- *Published research on estimating land use and land cover change by augmenting field inventory data with remote sensing observations* – Research findings revealed the temporal patterns and

thematic transitions associated with forest cover loss by augmenting traditional forest inventory data with remotely sensed observations, photo, and satellite imagery. The article also includes recommendations on how to harmonize ground and remote sensing observations through a defined enhanced plot interpretation process.

- *Supplied 324 spatial data requests and almost 1.4 million online data requests and responded to almost 1,500 consultations, investing 16,735 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.

- *Provided technical assistance to customers* – FIA National Inventory and Monitoring Applications Center (NIMAC) provides technical assistance on planning, conducting, processing, and analyzing forest inventories to FIA's broad range of customers, including NFS, other Federal agencies, State governments, and other countries.

- *Sought input from partners and supporters through meaningful national and regional engagements* – FIA held 4 user-group meetings and 10 management meetings to ensure that the program is providing the highest quality service and meeting its planned objectives according to the goals stated in the FIA strategic plan and on-going commitments made to our partners. Of the total meetings, eight were national in scope and six were regional.

- *Published reports to support development of the upcoming 2020 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 RPA-LMP Data 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.

- *Provided U.S. forest sector carbon projections* in support of the United States of America in responding to the United Nations Framework Convention on Climate Change, including development of the Nationally Determined Contribution, the Fourth Biennial Report, and the Long-Term Strategy.

- *Co-sponsored an international conference of the International Boreal Forest Research Association* held (virtually) in Fairbanks, Alaska, August 16-20, 2021 (proceedings in preparation).

- *Published national-scale forest sustainability indicator reports* on (1) the productive capacity of forest resources; (2) forest ecosystem and harvested wood products carbon balances; and (3) selected socioeconomic indicators describing payments for ecosystem services, socioeconomic conditions in forest communities, and forest based recreation activity—the published reports are produced on a rolling basis. The 2021 publications updated 11 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. (See https://www.fs.fed.us/research/sustain/criteria-indicators/).

- *Classifying forest type in the national forest inventory context* -- Developed a methodology that uses a combination of airborne hyperspectral and lidar data to map forest inventory and analysis (FIA) program defined forest type between sparsely sampled FIA plot data collected in interior Alaska. The random forest classification algorithm with hyperspectral vegetation indices and lidar-derived topography and canopy height metrics had the highest accuracy.

- *Landsat forest height signal saturation reduced using new GEDI LiDAR asset on Google Earth Engine* -- While Landsat has proven to be effective for monitoring many elements of forest condition and change, the platform is limited in measuring forest structure, which determines several key ecosystem functions. Results suggest Landsat-based maps of components such as height may substantially benefit from local calibration with dense, global sample of LiDAR observations collected by NASA's Global Ecosystem Dynamics Investigation (GEDI).

Forest Inventory and Analysis continued leading implementation of policy change on agreements and published a record number of publications

Since FY 2020, 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. Revising the traditional entry into formal partnerships also ensured FIA acknowledgement and recognition of all products and derivatives built from FIA data and produced by third parties. In

addition, to best protect FIA assets, this policy change demonstrated to our partners and clients the extent of their investments in products produced in partnership with other institutions.

To protect 325,000 plot locations across 50 States and U.S. islands, landowners' personally identifiable information, nonpublic 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), in cases where it was necessary to hold parties legally accountable for the established commitments and terms agreements. In 2021, FIA entered into the following new agreements: 35 MTAs, 18 joint venture agreements, 11 interagency agreements, 1 international joint venture agreement, and 1 participant agreement (table 1).

.Table 1. Number of new FIA agreements entered with partners, 2019-2021

	2019	2020	2021
Material transfer agreement	0	30	35
Cooperative research and development agreement	0	1	0
Memorandum of agreement	0	3	0
Memorandum of understanding	23	5	0
Interagency agreement	7	5	11
Memorandum of cooperation	0	0	0
Cooperative agreement	0	2	0
Joint venture agreement	28	18	18
International joint venture agreement	0	1	1
Participating agreement	2	2	1
Total	**60**	**67**	**66**

The FIA program published 239 publications, a 17-percent increase from last year, including 107 core publications (reports specific to a complete survey unit, complete State, national forest, or national reports), and 101 journal articles. Of the published core publications, seven were 5-year State reports, analyzing inventory data collected in previous years for the States of New Hampshire, New York,

Vermont, Mississippi, Texas, California and Coastal Alaska; and three inventory reports for the U.S. Virgin Islands, American Samoa, and Guam. Published research articles included the following areas of work: forest carbon and biomass, land use and land cover change, small area estimation of forest inventory, urban inventory, interior Alaska inventory, ecosystem health estimations, forest products and utilization, forest ownership, geospatial analysis and products, and statistical data processing, analysis, and delivery. The number of FIA publications per analyst and researcher averaged 2.8 for the entire program.

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 use 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 eight 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 range-land 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 news, products, links & activities

- Campaign: Trees for Community Recovery

- Federal Registry Notice: Identifying barriers to advancing racial justice and equity and support for underserved communities at USDA

- Project Learning Tree – A guide to teaching and learning about forests

- Associated Press – Young adults' relocations are reshaping political geography

- WV Public Broadcasting – Research reveals clean air makes stronger forests

- USDA Forest Service – New web resource: The need for field-based tree monitoring

- ESRI – Urban parks play a key role in curbing inequity and climate impacts

- USDA Forest Service funds [15 Landscape Scale Restoration projects in Northeast, Midwest](#)

- National Public Radio – [What the cherry blossom bloom can tell us about climate change](#)

- Smart Cities Dive – [Pittsburgh applies equity lens amid push to plant 100K trees](#)

- American Forests – [Seeing the city for the trees](#)

New and Recent Research

- Dye, Alex W.; Kim, John B.; McEvoy, Andrew; Fang, Fang; Riley, Karin L. 2021. [Evaluating rural Pacific Northwest towns for wildfire evacuation vulnerability](#). Natural Hazards.

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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 and provide the information technology needed to disseminate those results. Audiences include the scientific community, landowners and resource managers,

academics, policymakers, the public, and students. 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 (FS) Research & Development (R&D). 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. Specifically, KMC:

- Plays a leadership role in the Forestry Research Advisory Council (FRAC) Federal Advisory Committee. The FRAC meets annually to present recommendations to the Secretary on the Forest Service R&D program and consists of up to 20 members appointed by the Secretary of Agriculture from Federal, State, university, industry, and nongovernmental organizations.

- 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, landowners and resource 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 plain language.

- Provides Records Management such as planning, controlling, directing, organizing, training, promoting, and other managerial activities involved with respect to records creation, records maintenance and use, and records disposition in order to achieve adequate and proper documentation of the policies and transactions of the Federal Government and effective and economical management of Agency operations. The program lead for KMC is required to create and manage information that documents our work, safeguard information that needs to be protected, and keep or dispose of Federal records according to an approved records schedule -- A records schedule is a document that states how long to keep specific types of records and what should happen to those Federal records when no longer needed. 36 CFR 1220.14

Recent achievements

R&D WO Newsletter: Produced 12 monthly newsletter issues on time. Recruited 1,100 new subscribers in 2021, including leaders in the Forest Service and partner organizations and Congressional staffers. There are nearly 11,000 subscribers from the Forest Service, other Federal

agencies, State or local governments, nonprofits, universities, and the public. Many of these subscribers forward the newsletter to others, so its reach is likely well beyond 11,000. Infographics featured in the newsletter are multipurpose and 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: 118 highlights originating from the Research Stations were reviewed, edited, and will be made available on the web.

Other High Impact Products: Produced four new glossy factsheets:

- Postfire Stabilization and Recovery;

- Wood Innovations for a Sustainable Future

- Forest Carbon Estimation and Monitoring

- Forest Carbon Status and Trends

All factsheets are in production. Also produced 2021 R&D At-a-Glance brochure, and "A Sample of Recent Research Accomplishments: Science and Innovation for a New Century of Conservation

*(*Informally called "Greatest Hits"). 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

Facebook and Inside the Forest Service: Provided postings for these outlets on a regular 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 10 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.
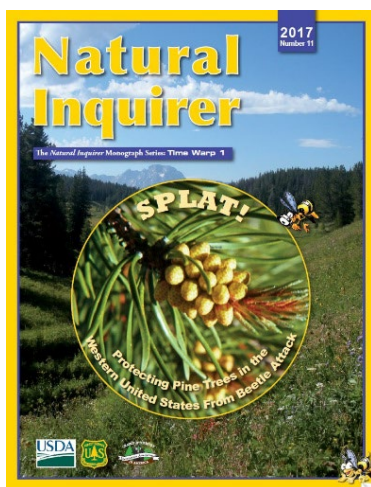
The *Natural Inquirer* program creates and distributes re-usable science journals and materials written for K–12 students. In FY 2021, approximately 94,201 of these products were distributed to classrooms, homeschools, and individuals across the country. It is notable that the COVID-19 pandemic affected our work during FY 21. All work is done with our nonprofit partner, the Cradle of Forestry in America Interpretive Association (DBA FIND Outdoors), and the University of Georgia. https://naturalinquirer.org

Important FY 21 program accomplishments

*Note: The COVID-19 pandemic had a major impact on our distribution and event participation this FY.

By the Numbers

- 36,203 journals, booklets, and activity guides distributed

- 52,998 scientist and engineer cards distributed

- 86,914 unique visitors to *Natural Inquirer* website (Dec 2020 & Jan 2021 did not have data due to a glitch in the website)

- 30,000 Woodsy Owl 50th birthday cards (5,000 through *Natural Inquirer* and the balance through the National Symbols Cache)

- 100 Science Hours (available on *Natural Inquirer* website and social media only) Science Hours highlight a *Natural Inquirer* article and activity that a student can do in about an hour. It is one of distance learning outreach products. https://www.naturalinquirer.org/Science-Hour-v-249.html

- 620 Forest Service volunteer hours to help create products from FS retiree (equivalent paygrade GS-14)

- **Grand total:** 94,201 of these products were distributed to classrooms, homeschools, visitor points of contact, and individuals across the country in FY 21

Products Published

- Cream of the Crop *Natural Inquirer* monograph

- Knock on Wood *Natural Inquirer* monograph

- Woodsy Owl 50th Birthday Scientist Card

- Meet Dr. Jovan *Natural Inquirer* Reader (with Woodsy Owl)

- Distance Learning Modules (Smokey Bear, Capitol Christmas Tree, Climate Change) (available on *Natural Inquirer* website and social media only) https://www.naturalinquirer.org/Module-page-v-312.html

- Research FINDings

Social Media

- Instagram- (began building Instagram presence this year, reaching new people, between 500 and 700 views a month)

- Twitter- maintaining our Twitter presence with 2,064 followers

- Facebook- increased our followers from 1,726 to 1,787

- Pinterest- 304 followers, 53 pins, 184 monthly views, and 9,877 impressions

In Production

- Pacific Islands *Natural Inquirer*

- To Harvest or Not to Harvest *Natural Inquirer* monograph

- The Bee Frequency *Natural Inquirer* monograph

Upcoming Products

- Woodsy Owl "Lend a Hand, Care for the Land" journal

- Moon Trees monograph

FY 21 Partnerships

- Forest Service Conservation Education

- Forest Service National Symbols program (Woodsy Owl)

- Forest Service International Institute of Tropical Forestry

- Forest Service Pacific Southwest Research Station

- NASA for the Moon Trees project*

- 4-H

*The Moon Trees project is a joint project between the Forest Service and NASA that celebrates the 50th anniversary of the original Moon Trees that were brought to space and returned to Earth by Stuart Roosa. Roosa was a smokejumper for the Forest Service, who later became an astronaut. In celebration of the 50th anniversary of the Moon Trees and NASA's return to the moon with the Artemis mission, a new batch of tree seeds will be sent to the moon and returned to Earth for distribution at a variety of educational and public spaces. There will be ongoing educational outreach and Moon Tree data gathered from this project.

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 multistory 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 DC. 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 1 of 7 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.

- Robust science communications and science delivery platforms that host regular webinar series, trainings, digital science briefs, and science roundups.

- Data visualization and digital storytelling through innovative platforms, include Tableau and StoryMaps.

- 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.

Specific Science Delivery Projects Include:

Rooted in Research

Rooted in Research is the station's new science delivery platform. Focused on synthesizing science to natural resource managers and policy advisors, Rooted in Research supports the integration and use of best available science in natural resource planning and management across the Station footprint. This platform highlights emerging research topics relevant to land managers with the intention of promoting strong science-manager integration by making current research more available to busy resource managers. Rooted in Research is a multichannel platform, distributed via Constant Contact, and includes:

1. **Rooted in Research bimonthly publication**

   This digital publication focuses on the management implications of new science findings for natural resource managers through providing technical scientific information to our stakeholder base.

2. **Rooted in Research Webinar Series**

   Launched in February 2021, the Rooted in Research Webinar Series discusses research with a direct land management application. All webinars are interactive and targeted toward a land manager audience. Webinars follow a format of 30-minute presentation/30-minute Q&A and discussion.
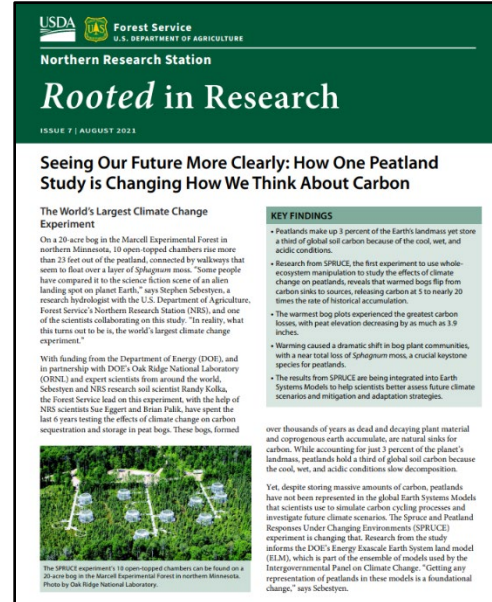
3. **Rooted in Research Science Roundup**

Based on input from land managers, Rooted in Research Science Roundup is designed to provide a quick look at emerging, locally relevant research around high priority themes such as climate change, water, and fire.

Fueling Collaboration

Fueling Collaboration is a virtual panel discussion series developed by the Northern Research Station, Southern Research Station, and members of the Joint Fire Science Program's Exchange Networks in the East. This panel discussion series brings researchers and managers together to learn about and discuss emerging topics in fire science research, with a focus on practical management considerations. The goals of this panel discussion series are to communicate Forest Service Northern and Southern Research Station fire science, build new and lasting science/manager connections, and elevate the profile of fire science in the East. Topics include Fire and Timber Management, Fire and Climate Change, Fire and the Wildland Urban Interface in the East, and Fire and the Carbon Cycle.

SCIENCEx

SCIENCEx is a new cross-station webinar series focused on bringing together scientists and land management experts from across R&D to explore the latest science

and best practices for addressing natural resource challenges across the country. On a quarterly basis, SCIENCEx is organized as week-long webinar "blitzes" around salient topics, allowing for deep-dives into subtopics or dynamics within specific geographies. From November 2020 to November 2021, SCIENCEx has showcased a diversity of R&D science and enjoyed excellent engagement. Nearly 5,500 people have attended 20 webinars that have featured 60 R&D scientists. Continuing educations credits (CECs) have been arranged by webinar organizers and help managers meet these CEC need. Each webinar features scientists from across R&D. Webinars average 200–250 attendees each day.

Fernow Experimental Forest Key to Delisting of an Endangered Plant

Running buffalo clover was listed as an endangered species in 1987; it was identified on the Fernow Experimental Forest (Fernow) in 1993. Then Project Leader Clay Smith responded quickly and worked with the U.S. Fish and Wildlife Service to protect the plants and allow for long-term silvicultural research to continue. Those actions became an unplanned experiment in the ecology of running buffalo clover when more plants were discovered on new skid trails built to avoid the other plants. Publications by Northern Research Station (NRS) scientists in 2002 and 2013 described the habitat of running buffalo clover on the Fernow and documented the importance of disturbance in maintaining populations. Staff and volunteers have monitored running buffalo clover populations since 1994, and a recent analysis of 20 years of data lends support for the published findings showing the association between sustained periodic disturbance and running buffalo clover abundance. Some sites on the Fernow with no management or no recent harvest activity were found to have negative trends of running buffalo clover over time. USDA Forest Service monitoring of running buffalo clover on the Fernow has been shared with partners and this work directly contributed to the decision to delist the species. Through the years,

NRS scientists have also been members of the recovery team and helped in development of management plans for the species.

How Does Forest Canopy Management Really Affect Wildfire Behavior?

Forest managers use tools such as mechanical thinning of stands and prescribed fires to reduce fuel loads and the likelihood of future severe wildfires in fire-prone ecosystems. However, the reduction of midstory and understory vegetation does not drive fire behavior in isolation. A Northern Research Station scientist partnered with scientists from the University of California Irvine, the Southern Research Station, Tall Timbers Research Station, and Los Alamos National Laboratory in a study using the FIRETEC fire-behavior model to investigate how the factors of midcanopy fuel loading, fuel moisture, and wind interact to ultimately affect how fires spread through a forest stand containing longleaf pines, common persimmon, and turkey oak. The study showed that the desired outcome of lower fire intensities via the application of fuel-load reduction strategies is highly sensitive to fine-scale changes in local wind conditions and fuel moisture. In dry conditions, too much thinning can introduce more windy and turbulent conditions, which can increase fire intensity. But doing no thinning can also lead to an increase in fire intensity when fuels are dry. When fuels are moist and windy conditions are present, reduced midcanopy fuel loads via thinning can also increase fire spread rates. This study and other fire-behavior modeling studies provide valuable information to forest managers that can guide them as they develop fuel reduction strategies to mitigate wildfire risk.

Rise and Fall of Black Cherry Tied to a Forest of Unintended Consequences

In the heart of black cherry's native range, including a region that bills itself as the "Black Cherry Capital of the World," the tree's regeneration, growth, and survival have been declining for over a decade. Regionally, black cherry is a foundational species providing excellent wildlife habitat and serving as the backbone of a high-value timber economy. A team of scientists from the Northern Research Service and University of Missouri synthesized long-term experimental records in the region in addition to Forest Inventory and Analyses data to examine the leading hypotheses for the tree's waxing and waning fortunes. They concluded that fluctuating black cherry dynamics are the unintended consequence of actions and policies often unrelated to land management activities. High deer populations and elevated nitrogen deposition favored black cherry over other tree species during much of the 20th century. Presently, however, decreases in nitrogen following the Clean Air Act Amendments, increased pathogen effects, and a warmer and wetter climate negatively affect the species. The researchers conclude that observed changes in black cherry dynamics may herald impending changes to forest health, local economies, and forest ownership patterns as other tree species respond to changing environmental conditions and biotic stressors over the coming century.

With Help from Two States, Two National Forests, and Scientists, a Songbird is Making Itself a New Home in Missouri

Exploitative logging and the loss of most of the shortleaf pine woodlands in the Missouri Ozarks led to the extirpation of the brown-headed nuthatch in Missouri more than a century ago. Decades of pine woodland restoration by the Mark Twain National Forest and other agencies over the past several decades, which included using prescribed fire and thinning, created more than 150,000 acres of habitat suitable for the reintroduction of brown-headed nuthatch. A team that included the Northern Research Station, Mark Twain and Ouachita National Forests, Missouri Department of Conservation, University

of Missouri, Tall Timbers Research Station, and other partners began reintroducing the bird in 2020. In August, 56 birds were captured on the Ouachita National Forest in Arkansas and released in restored pine woodlands on the Mark Twain National Forest in Missouri. Forty-six birds were released in August 2020, and monitoring revealed that most of the birds survived and four successful nests were documented. With the reintroduction of birds in 2021, the team exceeded the initial goal of reintroducing 100 brown-headed nuthatches by exactly 2 birds. While generally considered restoration, this project is also a test of a climate adaptation strategy because this ecosystem and species may need to move north with climate change.

Speeding Up Science: Modeling Used to Anticipate Outcome of Climate Adaption Treatments in Minnesota's Pine Forests

The Cutfoot Experimental Forest in Minnesota is home to one of the Nation's largest climate adaptation experiments—the Red Pine Adaptive Silviculture for Climate Change (ASCC) experiment established by Northern Research Station scientists in 2014. The Red Pine ASCC is evaluating adaptation approaches for iconic northern pine forests that range from doing nothing (control), to thinning pines to fewer trees per acre to increase soil moisture availability (resistance), to combinations of harvesting and planting of native future-adapted tree species (resilience), or novel species (transition). The ability to say anything definitive about long-term outcomes of these treatments is limited by the newness of the project. This is where computer modeling comes in. Northern Research Station researchers have used the Forest Vegetation Simulator (FVS), a computer model used by most National Forests, to evaluate long-term responses to the ASCC treatments. The results point to the transition treatment showing the lowest end-of-century mortality, increasing tree productivity compared with the other treatments, and

greatest tree diversity. This work provides an important context for silviculture aimed at climate change by offering insight into potential long-term outcomes of near-term treatments.

In a Region Valued for Water, Habitat and Lumber, Hydro-Ecological Modeling is Informing Management Decisions

Soil moisture is a critical driver of hydrological and ecological processes including stream flow, forest productivity, nutrient cycling, and wildland fire behavior and effects. It also influences ecosystem structure and tree species distribution across regional and local scales. Hence, land managers need high quality information about soil moisture distribution both spatially and through time to inform their decisions. Researchers from the Northern Research Station are working with the Canaan Valley Institute to implement the Regional Hydro-Ecological Simulation System (RHESSys) to better understand how spatial and temporal variability in soil moisture and water stress influences several ecosystem processes in Midwestern and Eastern U.S. forests. At the Fernow Experimental Forest in WV, researchers are modeling how forest succession and changing climate interact to alter water yields in the central Appalachians which provide drinking water for millions of people. A second effort involves assessing historic and potential future habitat suitability for oak savannas and woodlands across a gradient stretching from Oklahoma to the Appalachians. Savannas and woodlands provide critical wildlife habitat and raw materials for local industry. Hydro-ecological modeling efforts will help managers determine where and when to focus prescribed fire, silvicultural, and restoration treatments to maintain the critical services that savannas and woodlands provide.

Managing Forests for Soil Carbon: Protecting an Invisible Resource

In the Lake States, soils hold well over half of all forest carbon. Until now, researchers have not known how management affects the size of this resource—the largest single pool of forest carbon—at the landscape scales where many management decisions are made. Thanks to an analysis of existing data from a range of sources, Northern Research Station scientists and their partners can now offer forest managers the information they need to incorporate soil carbon into planning, assessments, and operations for a region that covers 6 percent of the land area but holds almost 10 percent of the forest soil carbon in the United States. The team established that soil properties such as texture mean the difference between significant gains and significant losses of carbon when forests are harvested. Researchers also revealed how past management, such as Civilian Conservation Corps reforestation, continues to support soil carbon sequestration and highlighted the contribution of reforested minelands in sequestering soil carbon. To make their results usable, the team published a map of forest harvesting impacts on soil carbon that is now in use on three National Forests across the region, and a menu of place-based options to protect against losses or enhance potential gains in soil carbon.

With Reboot, Climate Change Atlas Updates Habitat Modeling and Introduces Tree Migration Projections

The Climate Change Atlas is the most popular Northern Research Station online tool, with an estimated 860,000 visitors annually. The atlas delivers information about current and potential future habitat suitability in the Eastern United States; version 4 includes a new feature that allows users to quantify the likelihood of tree migration potentials. The Tree Atlas, a component of the Climate Change Atlas, has been expanded to provide current information for 148 Eastern United States tree species and future

projections for 125 of the species; these changes are based on new models published in 2019. Maps and statistics are provided for individual species, while regional summary tables aggregate species information for national forests, national parks, watersheds, ecological regions, States, and 1-degree grids. Four tutorial videos help users understand the information and products, and guide navigation of the atlas. The newer models use projections from three general circulation models under two greenhouse gas emission scenarios to provide the upper and lower bounds of plausible conditions. Other improvements include a hybrid grid of 10×10 and 20×20 km cells, which increases the model information based on the density of forest inventory samples, newer Forest Inventory and Analysis data, and 45 updated environmental predictors. Users can now explore current and future habitat suitability and tree migration potentials to assist in management planning of forest resources.

New Management Guide Translates Research Results for Family Forest Owners

Since 1950, scientists with the USDA Forest Service, Northern Research Station have been studying more than a dozen approaches to forest management on the Penobscot Experimental Forest in Maine. The findings highlight advantages and disadvantages of different approaches to harvesting, including changes in wildlife habitat, carbon storage, aesthetics, and wood production. To bridge the divide between scientists and the public, the Northern Research Station scientists partnered with the University of Maine, Maine Audubon, and New England Forestry Foundation to publish a guide that translates research results into easy-to-understand language. The new guide "Managing your Woodland – Forestry Research Translated for Landowners" uses historical and contemporary images from the Penobscot Experimental Forest and elsewhere, descriptive text, and infographics to explain forests, forest management, and the short- and long-term outcomes of different approaches to harvesting. With this

information, family forest owners can make more informed decisions about their woodlots and better

achieve the outcomes they want now and in the future.

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 three priority areas for research (1) historical and future fire regimes, (2) fire- and carbon-oriented 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.

The first publication stemming from the initiative, *Hazards of risk: Identifying plausible community wildfire disasters in low-frequency fire regimes*, was published in 2021. Findings from this study were shared via a station-hosted webinar attended by county and State emergency responders and fire managers in October.

Carbon Dynamics Research for Land and Watershed Managers

In 2019, the PNW Research 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

BlueSky Framework: Upgrade to v4.3

The BlueSky framework, developed by scientists within the PNW Research Station, is used across the country to support air quality forecasting during wildfires and to plan prescribed burns. BlueSky links independent models of fire information, fuel loading, fire consumption, fire emissions, and smoke dispersion. In FY 2021, scientists updated several modules and added ones. They also added routines to ingest Canadian fire data and factor into daily smoke predictions. BlueSky output supports the Interagency Wildland Fire Air Quality Response Program and the air resource advisors deployed to wildfire incident management teams. Many regional and State agencies also use the daily BlueSky smoke predictions to forecast smoke and protect the public.

Evaluating Rural Pacific Northwest Communities for Wildfire Evacuation Vulnerability

Scientists with the PNW Research Station and their partners evaluated the evacuation vulnerability of nearly 700 rural communities in Oregon and Washington. Some of the most vulnerable communities were located along the western Cascade and Coast Ranges due to poor road networks. The findings have been integrated into the Risk Management Assistance Dashboard website used by Forest Service Fire and Aviation Management. County and State emergency responders and fire managers attended a

webinar about the study hosted by the station in July 2021.

Air Quality Conditions Now Available to the Public Through AirNow.Gov Map and Mobile App

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. Scientists with the PNW Research Station, other colleagues in Forest Service, and the Environmental Protection Agency made current air quality information available directly to the public through the AirNow.gov website and mobile app. Millions of people have visited the AirNow.gov website since its release, and it was highlighted by the White House as an important source of information for the public on air quality and smoke conditions.

Genetic Database Enables "Forest Forensics" for Investigating Bigleaf Maple Theft

Bigleaf maple (*Acer macrophyllum* Pursh) is among the most common targets of timber theft in western North America. Scientists with the PNW Research Station led development of a range-wide bigleaf maple genetic database to aid law enforcement investigations. It was used to successfully prosecute a theft of bigleaf maple from the Olympic National Forest. The genetic markers identified thru this research are also being used by the hardwood industry in the Pacific Northwest to manage clonal inventories in breeding populations and to evaluate marker associations with wood grain variation.

Communities Empowered by Collaborative Urban Air Quality Biomonitoring Project

Scientists with the PNW Research Station worked with community leaders and others to investigate the

distribution of heavy metals in air pollution in two Seattle neighborhoods adjacent to industrial areas. Moss collected from street trees revealed small-scale distribution and variability of metals in particulate matter. Concentrations of six toxic metals of interest were significantly higher in these neighborhoods compared to similar regional studies.

These findings are helping community leaders, regulators, and others strategically focus on improving conditions in the Georgetown and South Park neighborhoods within Seattle's Duwamish Valley. In response, community leaders requested follow-up air quality monitoring by regulatory agencies. These findings also informed recommendations for tree planting and "green" infrastructure that are now being funded through the city of Seattle.

Updates to Westside Elk Modeling Tools and Datasets

Newly revised tools enable users to project nutrition and habitat use for elk across 11 million hectares of western Oregon and Washington. Wildlife biologists and forest planners can also use the tools to evaluate the likely effects of management alternatives on elk habitat. A dual set of instructions provides guidance to those working within the Forest Service spatial analysis environment and for anyone using the models in a desktop application. The PNW Research Station hosted two virtual workshops in November 2021 for biologists and database managers. Feedback from attendees was used to finalize the user handbook.

PhenoMap: A Rangeland Management Tool

This web-based tool provides a method for closely monitoring rangeland vegetation as drought

conditions develop and subside during the growing season. [PhenoMap](#) uses satellite imagery to provide near-real-time information about plant life cycle events over large areas. It also allows comparison of current grass development to the historic annual greenness pattern. Range managers can use this information to make in-season adjustment to grazing practices.

Webinar Series on Drought in the Northwestern United States and Alaska

To increase preparedness for future drought conditions and support climate-informed decisions, the Northwest Climate Hub, housed within the PNW Research Station, and partners convened a bi-monthly webinar series and regular drought status updates for Alaska, Idaho, Oregon, and Washington. These efforts have reached thousands of people and provide critical information to support drought-related management decisions from the local to Federal level.

Identifying Environmental Conditions that Trigger Coho Salmon to Migrate and Spawn

Researchers found that patterns of river discharge and temperature appear to trigger upstream migration by coho salmon, whereas spawning appears to be triggered primarily by thermal conditions. The Oregon Department of Fish and Wildlife is using these findings as it develops a hydrologic model for the State. These findings will inform interpretation of patterns of river discharge and temperature during spawning, as well as the thermal effect of stream restoration actions.

Updated Web-Based Tools Help Natural Resource Managers Find Seed Sources Adapted to Future Climate

The [Seedlot Selection Tool](#) and [Climate-Smart Restoration Tool](#) have been updated to allow managers to input seed inventories and prioritize seedlots for a planting site based on the best match between the historical climate of the seedlots and the projected near- and long-term climates of the planting site. The new versions of these tools also allow users to input data from their own trials or published genetic studies to help find adapted seed sources.

Geneticists with the Forest Service's Pacific Northwest Region are using the Seedlot Selection Tool to design test plantations to study seedlot adaption and to evaluate how well their seed orchards will meet the needs for reforestation in a future climate. Geneticists in the inland West are using the Climate-Smart Restoration Tool to identify seed needed for postfire restoration and to help to ensure that the seed sources needed for future climates are conserved.

Enhanced Global Databases Facilitate Tracking of Deadly Amphibian Diseases

An international coalition of researchers, including scientists with the PNW Research Station, is working to minimize the spread of deadly amphibian diseases around the world through tracking, reporting, and development of biosecurity measures. In 2021, the coalition updated the [global ranavirus reporting system](#) and the [amphibian chytrid fungus online database](#), to include new web platforms for data archival with improved user capabilities. These publicly accessible online amphibian disease databases are used by scientists and managers worldwide to conduct research and address threats to many species of wildlife.

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 8 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

Identifying the wide diversity of stewardship organizations working on the Los Angeles River Watershed

The Los Angeles River Stewardship Mapping and Assessment project surveyed and mapped groups conducting stewardship work in the LA River Watershed. Results show a diverse group of stewardship groups engaging in social-ecological based stewardship, with a strong focus on place-based work, and the involvement of nontraditional groups such as colleges and universities. This information can be used to facilitate the NEPA process, promote collaboration among stakeholder groups, and identify partners and sites needing stewardship work.

Urban ecosystems are under increasing stress from an array of social-ecological challenges including climate change, land-use change, pollution, population growth, biodiversity declines, and social inequalities. Place-based stewardship is gaining increased recognition as a solution for achieving maintaining and/or restoring urban ecosystem health. Although they are usually not the primary landowners, stewardship groups take an increasingly greater responsibility for a wide range of land-use types including street and riparian corridors, watersheds, vacant lots, and public parks. The Stewardship Mapping and Assessment Project (STEW-MAP) is a national research program developed by the U.S. Forest Service that has been implemented at numerous locations in the United States and internationally. In 2019, researchers from PSW and the Los Angeles Urban Center partnered with Loyola Marymount University's Center for Urban Resilience to identify and map the different groups working stewardship-related activities in the Los Angeles River Watershed, including portions of the Angeles National Forest. In addition to research publications, the project will produce online interactive maps and tools that can support stewardship activities such as informing the NEPA scoping process; and identifying key stakeholders and potential partners. We found a diverse range of groups involved in stewardship of the watershed. Although the majority were nonprofits, there were also Government agencies, higher education institutions, for profit groups, and public private partnerships working across 41 types of sites. Notably, some of the groups worked at off-site locations, such as an indoor office or laboratory.

Furthermore, in addition to the expected focus on environmental issues, many of the organizations were involved with more social issues such as social justice, community improvement, education, and health. The presence of nontraditional stewardship groups has important implications for cities and Wildland - Urban interface land managers. Conventional views on what is environmental stewardship, and which types of groups undertake this work are often not inclusive, and risk excluding key partners. Instead, practitioners and researchers would do well embrace the concept of social-ecological stewardship and adopt a broader view of where the stewardship work can take place.

"All fish, all the time": a good general objective for fish passage projects?

In the effort to sustain animal populations of special concern on National Forest lands, the appealing notion of "habitat connectivity" has led to many efforts to increase it, often at considerable expense. In this study, Forest Service researchers used a novel individual-based, spatially explicit modeling framework to test the influence of different levels of habitat connectivity on the population dynamics of highly valued salmonid fishes. The results indicate partial connectivity of sub-populations within stream networks can yield the same benefits for population abundance as complete connectivity; this finding can lead to more efficient prioritization and design of habitat restoration projects.

Stream networks on National Forests contain many human-built barriers to movement by highly valued salmonid fishes. Many prioritization schemes for barrier removal use the assumption that allowing movement of, "all fish, all the time," is the most desirable restoration goal, but creating this level of connectivity can be expensive, and in some settings can conflict with other resource management goals. Better understanding of the degree of "passability" needed to sustain robust sub-populations upstream of barriers could increase the efficiency of restoration efforts. We used spatially explicit, individual-based

modeling of stream salmonids to explore the population-level consequences of various levels of upstream passability by adult fish only. In 30-year simulations, allowing resident adult salmonids (such as Cutthroat Trout) to move over barriers during only the highest 4 percent of streamflows yielded the same distribution and abundance of fish as allowing all fish unrestricted movement. In simulations of production from single years of spawning in a stream reach fully accessible to adult anadromous salmonids (such as Chinook Salmon), variation in the number of barriers to upstream movement by young salmon had no effect on the production of large outmigrants. Passage objectives less ambitious than, "all the fish, all the time," may often suffice to maintain populations.

Guidance for forest restoration following California megafires

2020 and 2021 have surpassed records for uncharacteristically large and severe wildfires in California and much of the West, and land managers are struggling to keep up with the need for postfire restoration efforts. To help address this challenge, Forest Service scientists and managers released a postfire restoration framework for California forest, chaparral, and sagebrush-steppe ecosystems and delivered findings to land managers and members of the public who have been impacted by giant wildfires in the past year.

A team of scientists from Forest Service research and management and other colleagues released a framework to guide post-fire restoration on national forests in California. The report highlights guiding principles, current tools for assessing postfire conditions, and case studies of applications of the framework to forests in the Sierra Nevada, chaparral in southern California, and sagebrush-steppe ecosystems in eastern California. Contributing scientists presented on their research to the Western Klamath Restoration Partnership, where Tribes and other communities were devastated by the Slater fire

in 2020, and national forest managers, Congressional staff, and stakeholders concerned about recovery from the enormous August Wildfire of 2020. Members of the team are working both to apply the framework to these recent megafires and to provide additional science guidance to address the growing challenge they represent.

The California Tree Mortality Network: Revealing the drivers and consequences of tree morality in the Central and Southern Sierra Nevada

Much of California experienced drought in 2012–2015. While consecutive years of drought are not uncommon in California, this drought was the most severe in 1,200 years in parts of the Sierra Nevada and likely foreshadows future impacts of drought under climate change. Working with managers and research partners, the California Tree Mortality Network provides data on the causes and consequences of tree mortality following drought. This information is used to develop and prioritize management responses aimed at increasing forest and community resilience.

The California Tree Mortality Network consists of 180 monitoring plots installed in 3 elevation bands on the El Dorado, Stanislaus, Sierra, and Sequoia National Forests. Each plot is surveyed annually to record changes in forest conditions following an extreme drought (2012–2015) and bark beetle outbreak (2014–2017). Observations from these plots reveal how levels of tree death have impacted forest structure and composition, fuel loads, fire risk and behavior, pollinator communities and invasive plants. Other efforts leverage these data to predict how carbon sequestration and storage trajectories have changed in the Sierra Nevada; to model and compare silvicultural alternatives for improving forest recovery; and to better understand relationships between water storage and drought stress in seasonally

dry forests. Working with managers, these data are used to develop and prioritize application of treatments to restore these forests and to increase resilience for future disturbances.

Working towards national wildfire prevention for the Republic of Palau

In FY 21, PSW scientists partnered with Palau's Network for Wildfire Prevention to host a quarterly wildfire webinar series for Palau focused on wildfire prevention, fire suppression, fuels mitigation, and restoration of wildfire impacted areas. This series has resulted in the development of a NWP Dry Season Response Plan to identify needs, strategies, and stakeholder partners for fire education and outreach to prevent wildfires that will be integrated into the development of a National Wildfire Protection Plan.

Through collaboration with the USDA–FS, the Ebiil Society has worked with partners across the Republic of Palau to establish the Network for Wildfire Prevention (NWP) comprised of members from across Palau's national government, State-level governments, and protected area network to address wildfire issues and work towards the development of a National Wildfire Protection Plan (NWPP). In FY 21, PSW scientists partnered with the NWP to host a quarterly wildfire webinar series for Palau focused on wildfire prevention, fire suppression, fuels mitigation, and restoration of wildfire impacted areas. This series has resulted in the development of a NWP Dry Season Response Plan to identify needs, strategies, and stakeholder partners for fire education and outreach to prevent wildfires that will be integrated into the NWPP. Webinars have also addressed wildfire suppression topics as well as incorporate a wildfire response drill and an onsite after-action review of Palau's largest recorded wildfire that occurred in April 2020. A need identified through webinar discussions was a way to assess fire risk to inform a fire danger warning system, public messaging, and risk mitigation activities. In response, partners from NOAA and Guam Department of Agriculture participated in a webinar on

Guam's Fire Danger Warning System that can be adapted for Palau through collaboration of the NWP, NOAA, and Palau National Weather Office. The webinar series will continue through FY 21 and PSW scientists will continue to provide technical assistance to support the NWP in its development of a draft NWPP for Palau.

Removing barriers to pile burning

A low-cost collaborative study has helped reduce fuel treatment costs and provided scientific information resulting in a local air board permitting the burning of plastic-covered debris piles.

A collaborative study between the national forests in southern California, PSW Research Station and the University of California-Riverside helped determine that burning silvicultural debris piles covered by polyethylene plastic did not change the smoke emissions. In 2016 it was estimated that the results of this study saved the FS and State agencies over $100,000 annually in labor costs. Recently, the results were used by the Klamath National Forest resulting in an air quality rule change by the Siskiyou Air District to permit the use and burning of polyethylene covered slash piles.

Collaborative use of post-fire restoration framework on the creek fire

The science-based, holistic, landscape scale postfire restoration framework from PSW-GTR-270 was applied to the 2020 Creek Fire in the southern Sierra Nevada. A categorized restoration priorities map was developed based on fire severity, fuels, natural regeneration potential, and drought risk, with special attention given to fishers and wildland-urban interface (WUI).

The Creek Fire (Sierra NF) was the largest single-fire (noncomplex) fire in 2020 and was the fifth largest in California's modern history at 379,895 acres, with almost half of it burning at high severity. Researchers from PSW and R5 ecology group formed a team to help tackle this massive scale restoration need following PSW-GTR-270's Postfire Restoration Framework to look at the larger landscape and help prioritize actions and areas. The team identified restoration objectives: restore forest resilience; maintain and promote Pacific fisher habitat and population corridors; reduce risk of future catastrophic wildfire, particularly around communities; and sustain future yellow pine mixed conifer forests in the near- and long-term. Forested areas where the fire improved conditions (low severity burn) were highlighted as areas to maintain and promote desired conditions. Areas where factors (such as high fuel loads and lack of natural seedling regeneration) threatened the sustainability as a forested area were considered for reforestation and fuels reductions if future climate conditions were faciliatory (low drought stress). Special consideration was given to fisher, an old forest specialist, since a large amount of its habitat and key population linkages burned. Areas of remaining good habitat were identified to be improved/maintained. Prioritization for reforestation, with a focus on black oak, was given to identified areas of degraded fisher habitat and drainages to allow for connectivity. This analysis was provided to the Sierra National Forest to aid them in prioritizing their restoration plans along with the help of local specialists and ground-truthing of this analysis.

Creating a new legacy: working together to save large trees

Following a century of fire exclusion, the forests in the Caples Creek watershed are at a high risk of wildfire and a prescribed fire was implemented to reduce fuel loads. In addition to supplying water to over 110,00 people, having never been logged, the watershed contains a high density of old forest trees. To reduce the risk of mortality to these trees during the burning operations, over 50 volunteers worked

to reduce fuels around 200 trees in the Caple Creek Watershed. By comparing data collected prefire and postfire across the 20,236-acre watershed, researchers at the Pacific Southwest Research Station in collaboration with the Cal Academy of Sciences and the Region 5 Ecology Program found that these community efforts not only helped protect large trees from fire mortality but helped to reduce future fire hazard.

To protect the many values at risk to wildfire, the Caples Creek Watershed Ecological Restoration Project sought to reduce hazardous fuels and restore watershed health in the drainage using prescribed fire. In preparation for the burn, over 50 volunteers worked to reduce fuels around 200 trees across 100 acres to protect remnant old growth forest and large, legacy trees from incidental fire mortality. By comparing data collected prefire and postfire across the 20,236-acre watershed, researchers at the Pacific Southwest Research Station in collaboration with the Cal Academy of Sciences and the Region 5 Ecology Program found that these community efforts not only helped protect large trees from fire mortality but helped to reduce future fire hazard throughout the watershed.

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, nonprofit 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; Maintaining Resilient Dryland Ecosystems; Human Dimensions; Inventory and Monitoring; Science Application and Communication; and Wildlife and Terrestrial Ecosystems.

The Rocky Mountain Research Station 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 and Development. This year, the website had over 1 million pageviews. 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) publications continue 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. SYCU is directly distributed to a mailing list of over 16,000. We produced a total of 25 SYCU publications in FY 21—7 *SYCU Bulletins* and 16 *SYCU (in 5 minutes).* We also took advantage of a continued high number of teleworking land managers with our SYCU webinar series in the spring of 2021. These 15 short, interactive land manager-focused webinars
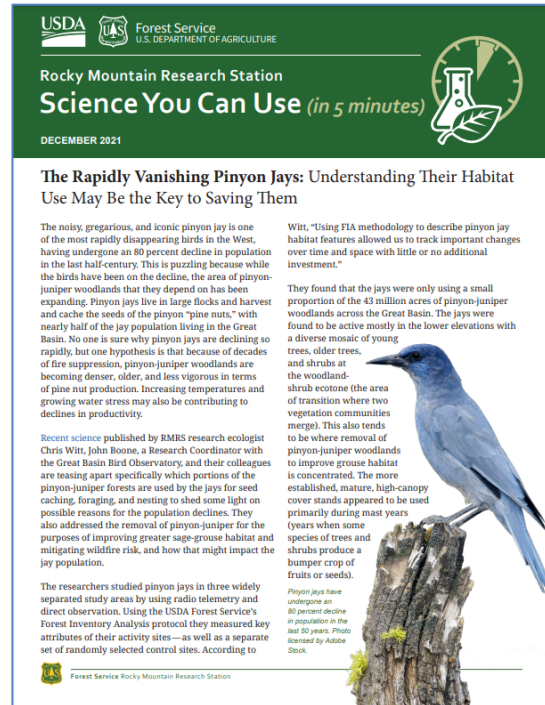
enjoyed excellent participation hosting nearly 2,300 attendees and resulted in 48,539 webinar

pageviews plus a 201-percent increase in pageviews from prewebinar associated webpage visits.

Introducing Charboss: New Mobile Biochar Production Machine Results From Forest Service and Industry Patent

The USDA Forest Service is driving the development of new technology for making biochar, a carbon rich soil amendment that can help restore degraded soil. Air curtain burners, also called air curtain incinerators or fire boxes, were designed principally as a pollution control device for open burning. The Rocky Mountain Research Station is partnering with industry and land managers to develop new air curtain burners that turn piles of unmerchantable wood waste into biochar. RMRS soil scientist Debbie Page-Dumroese and others are working with Air Burner Inc. under a Cooperative Research and Development Agreement to innovate ways to create useful biochar from woody biomass. The team was recently

The CharBoss team demonstrated how the equipment can be used to combat Gorse, reducing invasive species to create a product that can aid in restoration and enhance forest resilience and tree seedling quality (USDA FS photo).

awarded a patent for their mobile biochar production system designed for their air curtain burner. The new system is called the CharBoss. The CharBoss has the capability to separate charcoal from the burning biomass using a mobile through-put method, or conveyor belt, that expels the biochar from the burner and subsequently quenches it.

The CharBoss has fewer size and moisture content limitations than existing mobile biochar production machines, and it can consume material from most burn piles with minimal to no preparation. The new technology immediately quenches the coals to reduce the risk of fire and reduce waiting time for cooling before application or transport to another site. The team's current machine burns at a rate of 1 to 2 tons per hour. Recent Rocky Mountain Research Station research shows how biochar can enhance forest resilience and tree seedling quality. One goal of the CharBoss development is to recover or offset costs of land treatments to reduce nonmerchantable vegetation by producing a product that has value for augmenting and restoring degraded soils. On October 5, 2020, the CharBoss team held a field demonstration in Oregon to show off how the equipment can be used to combat the invasive woody shrub gorse; thereby reducing the biomass into a product that can aid in restoration. The mobile CharBoss system provides a landscape management opportunity and offers a value-added product for vegetation management activity that previously had none. This new mobile biochar technology provides forest managers with opportunities not only to remove unwanted biomass, but to benefit from the biochar created in the process.

PODs User Community Escalates Multi-Agency Engagement in Prefire Planning

Wildfire is becoming more frequent and intense across the country, and fire planning and management professionals are increasingly strained. Forest Service scientists develop tools and processes that can be used across boundaries to prepare for and respond to wildfire, such as Potential Operational Delineations (PODs) and several of the analytics hosted by the Risk Management Assistance (RMA) Dashboard. However, these tools require greater capacity and interagency coordination to provide the most benefit to communities facing wildfire. To generate solutions, the Rocky Mountain Research Station Wildfire Risk Management Science (WRMS) team convened the PODs User Community, a community of

practice to build innovation, collaboration, and capacity around spatial planning. The [Infrastructure Investment and Jobs Act](#) identified PODs as a critical tool for wildfire management, supporting its application and increasing the need for interagency collaboration with a $100 million investment to expand delivery and training for PODs planning.

The RMRS hosted the PODs: Collaborative Fire Planning Workshop on February 24–25, 2021. The workshop included case studies from the field, showcased how PODs have been adapted for a range of applications, and identified implementation barriers and opportunities to improve this collaborative fire planning method. Over 450 fuel planners, line officers, management planners, scientists, and consultants participated in the event. Recordings of each session of the workshop are available on the [PODs website](#).

The workshop also kicked off the PODs User Community, a group for PODs users, from experts to beginners. The User Community will continue to grow and adapt with PODs, as members of the group share their unique experiences with PODs on their local landscapes. The WRMS team at RMRS continues to advance PODs science, integrating feedback from the workshop as well as members of the User Community.

During the third virtual PODs User Community workshop November 3–5, 2021, over 150 participants including fuel managers, planners, and resource specialists had honest conversations about spatial fire planning opportunities and challenges. These user community meetings focus on PODs not as a stand-alone tool, but as a framework providing a natural springboard for developing risk-informed approaches to address emerging wildland fire management challenges.

New Approach for Estimating Rangeland Carbon Stocks Helps Managers Plan Climate Change Mitigation Strategies

Methods for estimating how much carbon is stored in rangelands have been lacking—until now. Using existing models and soil data sets, RMRS research ecologist Matt Reeves and a team of RMRS scientists and managers in the Intermountain Region developed a way to quickly assess rangeland carbon. And the great news—the process can be applied at local or larger scales. The technique involves assessing aboveground carbon stocks in shrubs and below ground in soil organic carbon, which varies by plant community type. Standing carbon can be calculated
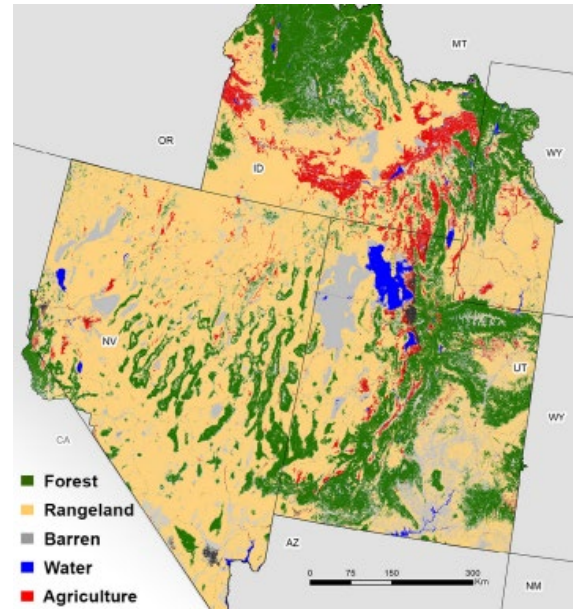
Map showing areas of rangeland (tan color) in the Intermountain Region. Map by Matt Reeves.

either from plot level inventories or from spatial data describing shrub cover, height, and species. The outputs help managers decide which types of management are most suited to maintaining or increasing carbon levels above and below ground and can be used to estimate where and how quickly ecosystems may change with a changing climate. The data are also useful for forest planning. This new approach was shared widely with managers as a Science You Can Use (in 5 minutes) publication.

FireWorks Curriculum Sparks Learning About Wildland Fire

The [FireWorks curriculum](#), developed at the Rocky Mountain Research Station, has brought the science of wildland fire to life in classrooms across the Western United States for more than two decades. Children living in the wildland-urban interface often grow up with the reality of wildland fire right in their backyards. Many students, however, rarely have an opportunity to learn about fire behavior, ecology, or preparedness. FireWorks provides teachers and students with [interactive lesson plans](#) and [trunks of materials](#) that help students understand the physical science of fire, the important role that fire plays in many ecosystems, and how human activities can influence fire. The program features engaging, hands-on activities, like the popular "Matchstick Forest," which lets students see firsthand how factors like slope and fuel density affect fire spread. Curricula are available for grades K–12 and are updated to include the latest science and educational standards. The program is widely used by teachers and fire educators across the West—in the Missoula area alone, the program reaches more than 1,400 students and 300 adults each year.

RMRS ecologist Ilana Abrahamson uses a FireWorks activity to teach students about how trees grow and how thick bark can help them survive surface fires. USDA Forest Service photo.

Simple, Fast, and Cheap: A New Photoload Sequence Building Technique for Fuel Load Estimates

The researchers measure the fuels and then collect them for drying and weighing in the lab. USDA Forest Service photo by Ian Grob.

Fast and efficient fuel loading estimates for fire-prone ecosystems are vital for accurately predicting fire behavior and effects. Fuel loads using photoload sequences are estimated by comparing the fuels on a landscape to a set of side- or downward-looking photos of simulated fuel beds with defined amounts of fuels. To create these photo sets in the past, researchers built simulated fuel beds by selecting, weighing, arranging, and photographing all materials and sequences in the lab. This process was time consuming and needed to be replicated for any new ecosystem. To improve accuracy and efficiency, Rocky Mountain Research Station scientists have developed a new method for creating photo sequences in the field. Using this new procedure, land managers will be able to more quickly create locally relevant photoload sequences to assess the fuel loads for their area.

The photoload technique provides a quick and accurate means of estimating the volume of wildland fuels on the landscape including 1-hour, 10-hour, 100-hour and 1,000-hour downed dead woody, shrub, and herbaceous fuels. This is done by visually comparing conditions in the field with a set of photographed sequences. It has been implemented in multiple inventory and fuel monitoring projects worldwide. A new land manager-focused comprehensive handbook from RMRS details this new procedure for creating a set of photoload sequences in the field with minimal effort by photographing local fuel beds in situ. This new approach was shared widely with managers as a Science You Can Use (in 5 minutes).

One-stop Shop for 27 Years of Mappable Information About U.S. Wildfires

As fire seasons become longer, the amount of land burned has become greater. Climate change and other factors have meant more wildfires occurring outside of historic fire seasons in different parts of the country and more extreme fire behavior. In order to improve our ability to predict, manage, and recover from fire, having data about how fire has behaved in the past is important. Rocky Mountain Research Station research ecologist, Karen Short, recently updated the Fire Program Analysis Fire-Occurrence Database. This database catalogues all wildfires reported in the U.S. from 1992 to 2018, representing a total of 165 million acres burned during the 27-year period. These data have served as critical inputs for many notable products, including a national wildfire hazard map and associated Wildfire Risk to Communities analyses. They are ready for use by fire managers, planners, decision makers, and others inside and outside the agency.

Two-Part Salvage Science Summit

During a two-part series on forest salvage, panels of experts and practitioners were brought together to discuss the operations, technology, and ecology behind post-fire salvage science. The Salvage Science Summit Series, in May and December 2021, was a collaborative effort between Rocky Mountain Research Station, Southern Rockies Fire Science Network, Northern Rockies Fire Science Network, and the

[Northwest Fire Science Consortium](#). The Summit featured scientists (including numerous Rocky Mountain Research Station researchers) and land management experts from across the country to provide guidance in post-fire salvage operations. As a discussion-based event, all presentations were previously recorded and available for participants to view ahead of time. Each day, presenters shared an overview of their recorded presentation followed by discussion and Q&A session. This webinar was open to all audiences.

Forest Management Science Highlighted at Western Governors Association Workshop

Scientists from the Rocky Mountain Research Station participated in the Western Governors' Association workshop on [Working Lands, Working Communities](#) held in Denver, Colorado, October 7–8, 2021. Rocky Mountain Research Station research forester [Nate Anderson](#) served as a panelist on the *Forest Management*

RMRS Research Forester Nate Anderson at the WGA Workshop (Courtesy photo by Ellen Jaskol).

Infrastructure Roundtable, where he delivered a short presentation on opportunities, barriers, and infrastructure for forest biomass and bioproducts. This science was developed with his Rocky Mountain Research Station colleagues [Debbie Page-Dumroese](#), [Dan McCollum](#), and [Jeff Morisette](#). The panel explored infrastructure needs for effective forest management and economic development tied to forest restoration and the bioeconomy. Specifically, Anderson discussed synergies between forest restoration, transportation infrastructure, investments in bioeconomy enterprise, and

workforce development. Watch this discussion and others from the workshop online. Moving forward, the Western Governors' Association is hosting webinars, work sessions, and podcasts to further examine these subjects. For over 100 years, Forest Service science has sparked innovations in forest products. Today, Forest Service science provides new uses and technologies for wood products and advanced bioproducts, such as biochar, cross-laminated timber, mass timber buildings, and more. These products, and associated processes and innovations, strengthen economies, and provide environmental benefits.

Management Practices for Limiting Soil Disturbance During Harvest Operation

Timber harvesting can negatively impact soil health required for sustained forest production. Limiting the degree, extent, and distribution of soil disturbance during harvest operations will help continue the production of ecosystem services and goods from national forests. To help achieve this goal, RMRS research soil scientist Debbie Page-Dumroese and colleagues authored a report (RMRS-GTR-421) titled "Soil Sustainability and Harvest Operation: A Review." This new resource highlights the science on long-term soil recovery after timber harvests and reviews types of impacts, effects of different harvest operation methods, and recovery times. A Science You Can Use (in 5 minutes) shared this new report with land managers.

A New Road Map for Forest Service Science and Management Partnering

Bringing bright minds together from across Deputy Areas into a unique partnership built around an adaptive learning framework is what the Science Partner Program is all about. This effort has been designed and piloted by the Rocky Mountain Research Station and Intermountain Region (R4). By

An example of one of the larger science partner program efforts, the Bridger-Teton National Forest and Rocky Mountain Research Station Scientists are collaborating in advance of Forest Plan Revision to get ahead of science-based needs that will inform the forest's process (USDA Forest Service photo by Nehalem Clark).

matching up research scientists with managers, this Science Partner Program has built positive relationships and networks between Research and Development and the National Forest System while working on specific, timely questions like: Can we downscale climate change maps to the National Forest level? How can we increase the accuracy and efficiency of Boreal Toad monitoring? And, how might we improve our rangeland monitoring that leverage the best data available?

The newly published Intermountain Region-Rocky Mountain Research Station Science Partner Program: A Road Map to Connecting Forest Service Science and Management (RMRS-RN-89) and companion Story Map provide a blueprint for how a structured partner program can yield new approaches. The Road Map highlights key components for success while also sharing lessons learned, challenges the program faced, and future opportunities. A section of the Road Map is dedicated to how this model of pairing science and management can be applied to forest planning. The Science Partner Program is co-led by Nehalem Clark (Rocky Mountain Research Station) and Natalie Little (R4), and the program teams include representatives from both the Rocky Mountain Research Station and R4. The program concept was conceived in 2016. This Road Map seeks to share inspiration for this type of coproduction

model with other land managers and scientists interested in knowing more about or creating these kinds of cross-agency connections. The science partner group members were instrumental in creation of the document, providing snapshots of what the 15 groups have set out to accomplish and lending valuable insights about what has been learned.

New Research Shows California Spotted Owls Benefit From Forest Restoration

Forest restoration treatments can reduce future fire severity and benefit populations of California spotted owls, even with temporary disruptions within owl habitats in the Sierra Nevada, California. This finding is showcased in "Forest restoration limits megafires and supports species conservation under climate change," a new research publication released in *Frontiers in Ecology and the Environment*. The research team also included collaborators from the USFS Pacific Southwest Research Station, USFS Region 5, University of Wisconsin-Madison, and University of California-Merced. The scientists developed a fire simulation model that predicted future severe fire across the Sierra Nevada through midcentury. The predicted amount of severe fire then changed as a function of simulated fuels reduction and forest restoration treatments. The fire model was then linked to a Sierra Nevada-wide population model of California spotted owls, which also responded to potential direct effects of treatments on owl habitat.

New Report Informs Sustainable Forest Management on the Black Hills National Forest

Rocky Mountain Research Station scientists published the general technical report, *A Scenario-Based Assessment to Inform Sustainable Ponderosa Pine Timber Harvest on the Black Hills National Forest*. The report, based on forest census data, provides context, rationale, and evaluation of harvest level scenarios across a range of mortality and growth rates in the Black Hills. This report offers scientific information that can inform discussions concerning future harvest levels on the Black Hills National Forest. A primary finding is that the current volume of standing live sawtimber does not support a sustainable timber program at recent rates of harvest, under a wide range of scenarios considering growth and mortality rates. This report along with other best available scientific information can support forest managers, Tribes, stakeholders, and the public in working together in future forest planning efforts on the Black Hills National Forest.
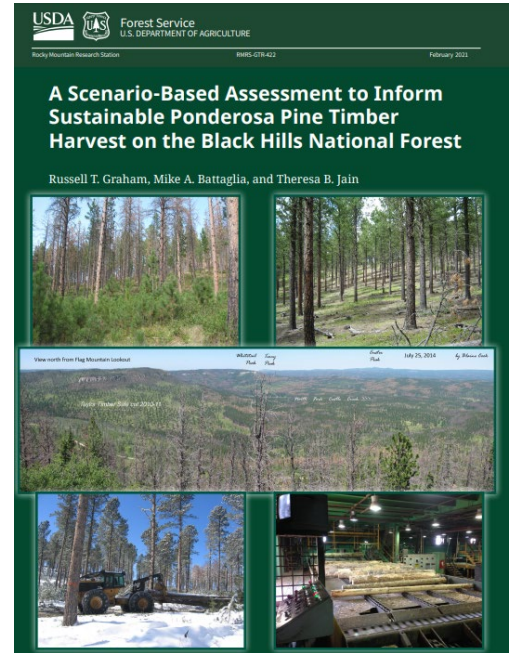
To ensure the highest quality data and scientific standards, a comprehensive review process was used. Scientists, technical and blind peer reviews, and an open public comment period produced over 350 comments. In response to reviewer comments, the final report contains 10 times the original number of possible future scenarios covering a wide range of mortality, growth, and harvest rates. General technical reports, such as this one, are scientific documents, not policy or decision documents. This report, the associated Forest Inventory and Analysis data, and a large body of science related to the Black Hills are available for land managers to consider. USDA Forest Service Rocky Mountain

Research Station also hosted a science-focused webinar to share the outcomes of the report on April 7, 2021.

**Cutting Edge Research on Decision Support Systems for Wildland Fire**

After several years of intense fires across the West, scientists have been working to develop new methods to support decision making. USDA Forest Service Rocky Mountain Research Station research foresters Dave Calkin and Matt Thompson assembled and authored cutting edge research as invited editors in a new special issue of the journal *Forests*. This issue compiles the latest science behind emerging decision support systems that help managers deal with the uncertainty of wildfire throughout the management cycle of planning, deciding, executing, monitoring, and learning. Managing wildland fire is inherently complex. Successful strategies require innovative partnerships between the research and management communities to create models that inform real-time decisions. Researchers from the USDA Forest Service Pacific Northwest Research Station contributed a publication to this special issue, "Hazards of Risk: Identifying Plausible Community Wildfire Disasters in Low-Frequency Fire Regimes." The authors hosted a webinar about the findings of this research on October 27, 2021.

Microscale Wind Modeling:

WindNinja for Fire

ManagementWindNinja, a tool developed by Rocky Mountain Research Station scientists, delivers high-resolution wind predictions within seconds for emergency fire responders making on-the-ground decisions. The program computes spatially varying wind fields to help predict winds at small scales
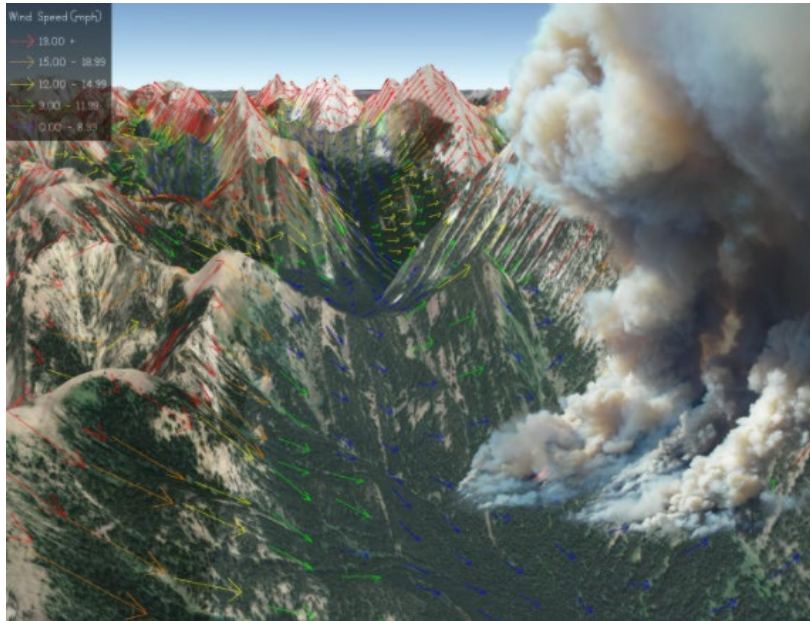
WindNinja is a model that simulates high-resolution winds in mountainous terrain and is designed specifically for use in operational wildland fire applications (USDA image).

in complex terrain. These predictions are extremely important in fire-prone landscapes where local changes in the near-surface wind are not predicted well by either operational weather models or expert judgment but are extremely important for accurate fire behavior predictions.

WindNinja performs microscale wind modeling and is typically run on domain sizes up to 50 kilometers by 50 kilometers at horizontal resolutions around 100 meters. This microscale wind modeling is used for a variety of tasks in wildland fire management, including planning, reconstructing past events, and exploring what-if scenarios. It is embedded within a number of operational systems routinely used by U.S. Interagency Wildland Fire response teams, including the Wildland Fire Decision Support System and FlamMap, and is also regularly used as a standalone model by both fire managers and on-the-ground firefighters in the United States and abroad. WindNinja can be run in three different modes depending on the application and available inputs. The first mode is a forecast, where WindNinja uses coarser resolution mesoscale weather model data from the U.S. NWS to forecast wind at future times. The

second mode uses one or more surface wind measurements to build a wind field for the area. The third mode uses a user-specified average surface wind speed and direction. This new tool was shared widely with land managers via a [Science You Can Use (in 5 minutes).](#)

Investigating Community Perspectives and Fuels Treatments in The Arctic

Rocky Mountain Research Station scientist [Patty Champ](#) will help co-produce a framework for research on fuels treatments in four communities in the Arctic through a new National Science Foundation grant. *[The National Science Foundation's Navigating the New Arctic](#)* program is funding a team of 11 researchers to assess fuel treatments as a strategy to reduce wildfire risk in Alaska and western Canada through the collaborative [Socio-ecological considerations for sustainAble Fuel treatments to Reduce wildfire Risk project (SAFRR)](#). This project is receiving funds as part of the larger $2.3 million NSF grant. The project team includes researchers from the University of Alaska Anchorage, Northern Arizona University (NAU), the University of Colorado (UC), Tanana Chiefs Conference (TCC), and [Rocky Mountain Research Station](#) economist and Wildfire Research, [WiRē](#), team member Patty Champ. *Navigating the New Arctic* projects address the convergence of scientific challenges in the rapidly changing Arctic.

Wildfires occur naturally in boreal forests, but they have become increasingly dangerous as the climate warms. The area of boreal forest burned each year in Alaska and western Canada has doubled since the 1990s, and the region has experienced some of the most deadly and costly wildfire events in the last decade. Effective fuel treatments such as thinning and prescribed burns require significant planning, implementation costs, and maintenance; and they may face resistance from nearby residents. The SAFRR project team will work with many stakeholder groups, including public land and wildfire

practitioners; Indigenous organizations; and, communities (Kenai Peninsula, Interior Alaska, Anchorage, Whitehorse, and Yukon Territory), to co-produce an integrated assessment of fuel treatments. The team will study how vegetation responds to different treatments. They will also analyze treatment costs, the acceptability to residents of different types of treatments in boreal forests, and how land managers can use fuel treatments to reduce wildfire risk.

Beetle Outbreaks in Subalpine Forests and What They Mean for Snowmelt

It is hard to overstate the importance of snowmelt as a source of fresh water in parts of the Rocky Mountain West, and great attention is paid to ecosystem water cycles in this region. Some of the snow that falls in the mountains goes directly from crystalline snow to water vapor, bypassing the liquid water phase. This phenomenon—sublimation—accounts for the loss of a large portion of the snowfall during the winter months in the Rocky Mountains. Snow intercepted by tree branches sublimates the fastest, often disappearing within a few days of a snowfall. Starting in the

Engelmann spruce trees killed by spruce beetle (right) in Wyoming's Snowy Range have far fewer needles to catch snow, compared to the living subalpine fir on the left. Less snow in the canopy leads to lower sublimation rates and more water being retained in the forest. Photo credit: John Frank, USDA Forest Service.

mid-2000s, a spruce beetle outbreak caused widespread damage to an Engelmann spruce subalpine fir forest in the Snowy Range Mountains of southeastern Wyoming. By 2010, the outbreak killed 75 to 85 percent of mature Engelmann spruce trees in some areas. The loss of the needles following the outbreak meant that less snow was being retained in the canopy and was instead falling through the tree branches

and onto the ground. Snow on the ground has less surface area, which slows sublimation, while the loss of canopy increases the amount of wind and sunlight reaching the ground, speeding up the sublimation of the snowpack. Recently published work by the Rocky Mountain Research Station teases apart how the loss of spruce canopy affects the sublimation rates for snow both in the canopy and on the ground in these ecosystems. And these findings have important implications to snow interception and retention for forest and water managers. These findings were shared widely with the RMRS land manager mailing list as a Science You Can Use (in 5 minutes).

Tree-Level Map of U.S. Forests Developed by RMRS Scientists

Scientists from the Rocky Mountain Research Station have created TreeMap, a first-of-its-kind tree-level map of the forests of the United States. Forest Service scientists developed TreeMap to understand the risks wildfire poses to carbon stored in forests. Current wildfire simulation models addressed the fire component of their question, but to tackle the carbon side, they needed information on U.S. forests at the individual tree level. That dataset did not yet exist at a national scale, and with over 2.8 billion pixels of imagery to populate, creating it was a daunting task. In a research paper published in *Nature Scientific Data,* the scientists, Karin Riley, Mark Finney, and Isaac Grenfell describe their innovative approach. TreeMap paired two databases: The Forest Inventory and Analysis database and LANDFIRE. FIA contains tree-level information from thousands of plots across the United States, but the plots don't provide wall-to-wall coverage. LANDFIRE provides a 30x30-meter grid of geospatial information like vegetation type and disturbance history for the entire United States, but lacks information at the tree level. Through an artificial intelligence technique, the scientists essentially matched each pixel of the LANDFIRE database with a forest inventory plot that best represented that area. For any 30x30-meter

pixel, a TreeMap user can download tree-level information and produce maps of those attributes, like tree density, heights, and species.

Beyond understanding fire risk to carbon, TreeMap has broad applications for land managers. It is already being used to inventory wildlife habitat, map forest types, and evaluate how proposed management actions may affect carbon stocks and local hydrology. Several of Riley's colleagues have been applying the dataset to improve firefighter safety by providing snag hazard maps for active fire incidents. Snags (standing dead trees) are one of the most common causes of firefighter casualties. Incident-specific maps are created and shared through the Risk Management Assistance Dashboard, giving incident response teams a quick picture of what conditions to expect on the ground, identifying hazardous areas, and ultimately improving firefighter safety. With TreeMap in hand, the Rocky Mountain Research Station team can now return to the broader question of how wildfire affects forest carbon, including expected emissions and how much carbon fires leave behind. Eventually, they hope to evaluate these impacts into the future, as changing climate and fire regimes reshape forests.

New Updates to the Wildfire Risk to Communities Website

Marking the 1-year anniversary of the Wildfire Risk to Communities website, the USDA Forest Service - with strong science input from Rocky Mountain Research Station Spatial Fire Analyst, Greg Dillon and our partners, Headwaters Economics and Pyrologix - have updated the website with new features. New features include the ability

to interact with wildfire risk data for your community, county, and State. New "expanded areas" show risk in populated areas outside official community boundaries. The update also facilitates comparing your community's risk to other communities in the county, State, or Nation. Prior to the update, community comparisons were limited to your State. The website is free and easy-to-use with interactive maps, charts, and resources to help communities understand, explore and reduce wildfire risk. The website

uses the best available science to identify risk and provide resources for communities to manage and mitigate risk. The resources at wildfirerisk.org are designed to help community leaders understand how risk varies across a State, region, or country and prioritize actions to mitigate risk. As a national project, Wildfire Risk to Communities is best for comparing risk among, rather than within, communities, and it is not designed for considering risk at the local, neighborhood, or individual home scale. Wildfire Risk to Communities is the Forest Service's response to direction in the 2018 Consolidated Appropriations Act (H.R. 1625, Section 210). In the legislation, Congress directed the Forest Service to produce a nationwide map that could inform communities about wildfire risk, help them understand their risk profile, and guide them toward steps to reduce their risk.

New Phenomap Tool Provides Range Managers with Real-Time Forage Conditions

Timing is everything, especially when it comes to the complex ecological interactions between plants and the environment. For range managers concerned with maintaining the integrity and productivity of rangelands, it is critical to monitor the seasonal conditions of grasses and other vegetation on which cattle graze. PhenoMap is a new Web-based tool that managers can use to assess the production and location of high-quality forage. PhenoMap uses satellite imagery to serve up near-real-time maps of

what is happening on rangelands over large scales. For instance, what is happening with western wheatgrass green-up or buffalo grass senescence can be detected via desktop. Phenomap allows range managers and producers to see what is happening across their areas of interest and perhaps make shifts in grazing with changing conditions. PhenoMap was jointly developed by researchers at the Forest Service's Western Wildland Environmental Threat Assessment Center, Pacific Northwest Research Station (PNW), and Rocky Mountain Research Station. PhenoMap was also featured in the new Rocky Mountain Research Station science delivery product: Connected Science. This new special series highlights important collaborations that deliver relevant, applied science about natural resources to people who make and influence decisions about managing land and natural resources.

Climate Change, Wildfire and Mexican Spotted Owls: Delivering the Most Recent and Best Science to Managers

Rocky Mountain Research Station scientists are working to understand how the changing climate and fire are affecting Mexican spotted owls, a threatened species found primarily in the Southwestern United States and Mexico. Across their range, a thirteenfold increase in the area burned is expected by the 2080s which could translate to large-scale habitat loss. As nesting environments become warmer and drier in future climates with predicted higher temperatures, owl nestlings may experience greater water stress. This means the owls could ultimately be pushed beyond physiological thresholds for survival. Rocky Mountain Research Station scientists and collaborators evaluated the annual climate cycle in the Sacramento Mountains of New Mexico. These climate change effects are likely to be apparent first in lower and warmer habitats occupied by Mexican spotted owls, therefore the research team recommend that

managers monitor the occupancy and reproduction in such areas to provide an early warning system for climate change effects.

The RMRS team has also launched the "Living Map" of Mexican spotted owl habitat, which includes annual maps of owl nesting habitat from 1985 to now. This map provides a living, updatable tool allowing managers to track changes in amount and distribution of owl habitat over time, and to better understand the effects of disturbance events such as wildfires on amount and distribution of that habitat. This knowledge will aid in integrating habitat needs of Mexican spotted owls with efforts to restore forest structure and more natural fire regimes throughout the Southwest, which is one of the major challenges facing managers in this region.

Global Technology Transfer and RMRS Entomological Expertise: Forest Service Scientist Identifies Important New Endemic Fly Species on Monserrat

Smaller than a house fly, both adults and larvae in the fly family Dolichopodidae (known as long-legged flies) are predators that play important roles in the ecosystems in which they occur. They feed on other small invertebrates and may play important roles in controlling mosquitoes, bark beetles, and agricultural pests. Yet even though there are more than 7,500 species of

RMRS Research Entomologist Justin Runyon has identified 11 new species of flies in the family Dolichopoididae on Monserrat. Photo by Catherine Wensink (UK Overseas Territories Conservation Forum).

Dolichopodidae worldwide, many undescribed species still await discovery. Rocky Mountain Research Station research entomologist and world expert on Diptera, Justin Runyon, has recently identified 63

species, including 11 new species of Dolichopodidae on Monserrat. These new species are described and illustrated in "The Dolichopodidae (Diptera) of Montserrat, West Indies." The new paper provides keys to the genera and species of Montserrat, summarizes their distribution, and provides additional new island records for many species.

These records and new discoveries are critical to understanding the diversity and distribution of long-legged fly species, information essential to manage and protect biodiversity. Six of the long-legged fly species are endemic to Montserrat and protecting their habitats can ensure conservation of these unique species. Protection of areas currently inhabited by these endemic species is among the highest priority conservation recommendations. Runyon also identified threats to the fly fauna on Monserrat, both natural and human.

Can Ponderosa Pine Bounce Back After High-Severity Fire?

Ponderosa pine forests were historically shaped by frequent, low- to mixed-severity fires. Land managers and scientists are concerned that recent high-severity fires, which have left expansive treeless patches in their wake, may prevent ponderosa pine from successfully regenerating in much of its former area. If ponderosa pine does not reclaim these sites, these areas will become grasslands, shrublands, or other forest types, such as aspen or Gamble oak. Rocky Mountain Research Station scientists and their colleagues examined the spatial patterns of ponderosa pine regeneration following fire, as well as the influence of environmental factors, such as distance to seed source, elevation, and other vegetation, on ponderosa regeneration success. They focused on large, high-severity patches in Arizona, Colorado, and South Dakota wildfires. Their results—shared widely in a recent Science You Can Use Bulletin—show that ponderosa pine generally regenerated in groups or clumps, rather than in a relatively homogenous

pattern, and the amount of ponderosa pine regeneration declined sharply with distance to seed source.

The researchers also found that ponderosa pine regenerated more abundantly in higher elevation sites

where climate tends to be cooler and wetter. Other vegetation generally did not negatively influence

ponderosa regeneration, and in many cases, had a positive effect on regeneration success, probably by

mitigating harsh site conditions. Downed logs also appeared to ameliorate harsh site conditions, to the

benefit of regeneration.

Overall, these results suggest that ponderosa pine may recover in high-severity patches that are close to

surviving seed sources, but in large patches far from surviving trees, ponderosa pine recovery may be

compromised, especially where growing conditions are harsh. These results can help managers better

anticipate recovery within high-severity patches, and in turn, better determine whether tree planting

treatments are needed to maintain ponderosa pine forests in the future as well as where and how to

conduct them.

Understanding and Managing Pinyon and Juniper Woodlands in a Changing Climate

Across the Western United States, pinyon and juniper woodlands are undergoing significant changes

that are of concern to land managers and the communities who depend on them. In some areas, the

woodlands are expanding, resulting in increased fuel loads, risk of more severe fires, and loss of high

value habitat for species such as greater sage grouse. In other areas, these woodlands are contracting due

to human development, more severe droughts, and larger wildfires. Rocky Mountain Research Station

scientists and their partners synthesized over 1,000 research and management papers on pinyon and

juniper woodlands in order to help land managers, researchers, and the interested public understand and

address these concerns. The resulting publication, The Ecology, History, Ecohydrology, and

[Management of Pinyon and Juniper Woodlands in the Great Basin and Northern Colorado Plateau of the Western United States](#) (RMRS-GTR-403), is designed to help managers quickly reference the current state of knowledge of these semiarid woodland ecosystems, prioritize areas where conservation and restoration efforts will have the greatest benefits, and identify appropriate management actions. The synthesis covers the ecology, history, and hydrology of these semiarid woodland ecosystems as well as The history of and responses to restoration and other management treatments. This reference was shared widely with land managers as a [Science You Can Use Bulletin](#).

Real-Time Forecasting of Wildfire Ignitions Across the United States

Dr. Ned Nikolov and his team at the Rocky Mountain Research Station [Rocky Mountain Center for Fire-Weather Intelligence](#) (RMC) has developed (in cooperation with Colorado State University) a unique new [forecasting tool](#) for quantifying the *chance* of wildfire start (ignitions) up to 10 days in advance on a uniform 20-km resolution grid across the conterminous United States. The new application became operational in the summer of 2021 and is accessible through the [RMC website](#). It produces probability forecasts for ignitions due to either lightning-caused, human-caused, or all-cause wildfires. At the core of the application is a comprehensive statistical model derived from a large amount of gridded 3-D meteorological data fields from NOAA's [NARR](#) database spanning the period 1992–2016, high-resolution vegetation cover and fuel maps, and [Karen Short](#)'s updated [Fire-Occurrence Database](#). An essential part of the ignition probability model is a module that forecasts *cloud-to-ground lightning* at 20-km resolution across the United States derived from observed lightning and meteorological data over a period of 24 years. Real-time lightning forecasts are also operationally available at the [RMC website](#).

Testing of Low-Cost Smoke Sensors

Wildland fires produce significant air pollution and real-time measurements of these pollutants are critical for mitigating the human health impacts of smoke. With climate change increasing the severity of the Western U.S. wildfire season, there is an urgent need
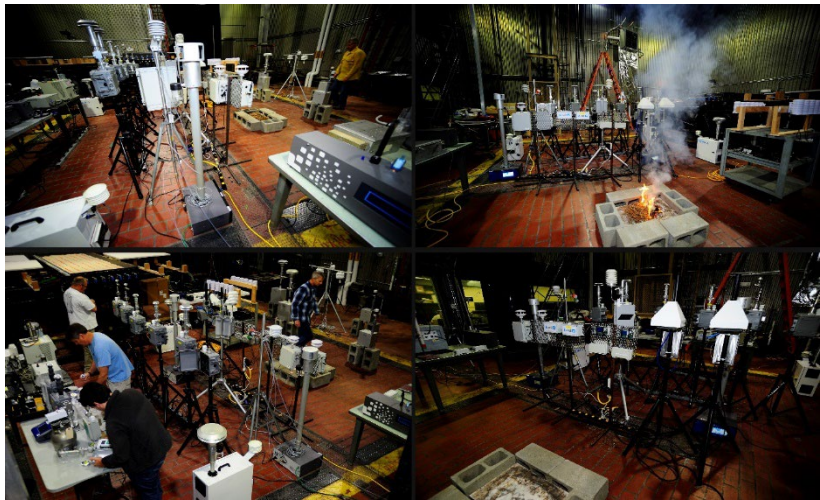
Smoke Sensor Testing at the Missoula Fire Lab

for new air pollution measurement technologies to reduce coverage gaps in existing air monitoring networks. The U.S. Environmental Protection (EPA) has partnered with Rocky Mountain Research Station (RMRS) Physical Scientist Shawn Urbanski in a multiyear effort to advance the development of new air measurement technologies for real-time smoke monitoring and to evaluate the performance of existing instrumentation in smoke impacted environments. In the initial project phase, several Federal agencies partnered with the RMRS/EPA team for the 2018 Wildland Fire Sensor Challenge which focused on low-cost, easily deployable sensors capable of measuring $PM_{2.5}$, CO, and CO_2. During the Sensor Challenge, prototype systems were evaluated in testing at the RMRS Missoula Fire Sciences Laboratory combustion facility. Several prototype sensors were identified for further development. In later project phases the second-generation low-cost sensors, some capable of measuring several air pollutants present in smoke, were evaluated by the RMRS/EPA research team in laboratory testing and multiyear field testing at the Mobile Ambient Smoke Investigation Capability (MASIC) site located on the Missoula Fire Sciences Laboratory campus. This project will ensure these low-cost smoke sensors provide accurate pollutant measurements and are suitable for use in the high pollutant concentrations

observed during wildland fire events. This new class of sensors will provide the ability to rapidly deploy an on-demand network that will guide smoke mitigation efforts, improve smoke forecasts, provide data for the validation and improvement of smoke emission and dispersion models, and support smoke exposure research.

The Great Basin Five-Needle Pine Proactive Strategy Engagement: A Collaborative and Science-based Approach

Great Basin bristlecone pine, limber pine, and whitebark pine protect watersheds, play important ecological functions, are symbols of perseverance and longevity, and are valued by the public. These high-elevation five-needle pines of the Great Basin face direct and indirect effects of climate warming and the threat of the continued spread of *Cronartium ribicola*, the nonnative fungus that causes the lethal disease white pine blister rust (WPBR). The Great Basin ecosystems are unique, and the scope of the threats requires landscape-scale solutions. The primary objective of this ongoing project, led by RMRS researcher Anna Schoettle, along with other scientists and managers, is to coordinate a cross-boundary partnership of managers, researchers, and professionals to identify critical information gaps and outline priorities for building a strong science foundation that can assist in timely decision making or managing and conserving the high elevation five-needle pines for resilience to WPBR in a changing climate.

We brought together representatives from the USDA Forest Service (R&D, NFS, FHP); U.S, Department of Interior's Park Service, Bureau of Land Management, and Fish and Wildlife Service; academia; and State, Tribe, and nongovernmental organizations for a field workshop in July 2021 in eastern Nevada to share knowledge and build a collaborative High-5 group in the Great Basin (Figure 1). This project was supported in part by the USDA FS R4-Rocky Mountain Research Station

BeSMART Program intended to spur Intermountain Region (R4) management-FS research partnerships to bring innovative approaches to management challenges.

Group photograph of the participants of the workshop in July 2021 (USDA Forest Service photo).

Carbon Monitoring System

The U.S. Forest Service is working to concurrently mitigate and adapt to climate change when managing the Nation's forests and rangelands, which have varying capacity to absorb carbon. Knowing the distribution of aboveground forest and woodland biomass across the landscape is crucial to inform management decisions. Accurately mapping aboveground biomass with confidence requires multiple sources of information, most notably forest inventory plot data, satellite imagery, and Light Detection and Ranging (LiDAR) remote sensing data. Tree measurements in field sample plots provide the biomass estimates needed on the ground. Satellite imagery captures variation in forest cover across space and through time. LiDAR is highly sensitive to variation in three-dimensional forest structure that relates closely to the distribution of biomass across the landscape and serves to bridge the scale gap between field plots and satellite imagery.

Research Forester [Andy Hudak](#) and Geographer [Ben Bright](#) worked with multiple stakeholders across Federal and State agencies, tribes, universities, and industry to develop a [Carbon Monitoring System](#) that leverages the respective strengths of forest inventory plot measurements, satellite imagery, LiDAR, aerial photography, topographic, and climate data to estimate forest and woodland biomass. The integrated maps of [forest](#) and [woodland](#) biomass (2000–2016) are available for the Northwest United States, and ongoing work will expand the maps to the entire Western United States (1984–2020). Furthermore, the integrated maps are a valuable resource in support of managers working to meet objectives of the 2012 Forest Service Planning Rule and the Forest Service's Shared Stewardship Initiatives.

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 and 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 nongovernmental 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 postdoctoral levels.

7.3. Metric Tables.

TABLE 1. Collaborative Relationships for Research and Development.
*ND-no data available.

Forest Service (FS)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total number active CRADAs[2]	74	22	58	102	205
Number newly executed CRADAS	34	9	36	50	40
All other newly executed non-CRADA/MTA agreements	ND	ND	ND	2,872	2,413

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)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total number new invention disclosures[1]	20	10	9	12	13
University co-owned	7	1	2	5	6
Total number patent applications filed[2]	11	7	7	10	12
University co-owned	6	0	1	5	6
Total number patents issued	5	5	3	4	4
University co-owned	4	4	0	0	1

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)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total number active licenses	19	9	11	13	7
Executed to small businesses	2	1	0	ND	ND
Executed to startup businesses	1	1	0	ND	ND
Executed to universities	16	1	0	ND	3
Invention licenses	19	9	11	13	7
Executed to small businesses	2	1	0	ND	ND
Executed to startup businesses	1	1	0	ND	ND
Executed to universities	16	1	0	ND	ND

ND = In progress but not
signed

**TABLE 4. Characteristics
of Income Bearing Licenses**

Forest Service (FS)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total number of income bearing licenses	19	9	11	13	7
Exclusive	18	9	11	13	7
Nonexclusive	1	0	0	0	0

E 5. Income from Licensing
*ND-no data available.

Forest Service (FS)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total income all active licenses	$2,634	$3,122	$800	ND	ND
Invention licenses	$2,634	$0	$800	ND	ND

ND = Funds not received in
2020

FY 19 FS Accomplishment Metrics in support of the REE Action Plan

Fiscal Year: 2020		
Products (Software/Web & Multimedia), Peer Reviewed and Nonpeer Reviewed Publications		
Outcomes	*Product Type*	*Total Entries*
Publications	Formally Refereed	1,289
Publications	Informally Refereed	528
Publications	Nonrefereed	87
Publications	All types	1904
Publications Articles	In Journals	1241
Publications Articles	Not in Journals	663
Science Delivery	Activities	1079
Science Delivery	Products	222
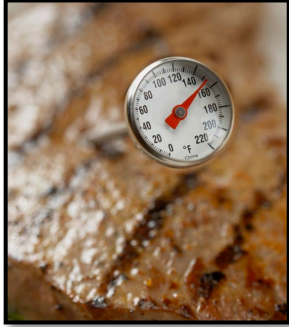
FSIS communicates safe food handling practices to consumers.

FSIS applies the latest technologies to ensure the safety of meat, poultry, and egg products.

FSIS activities lead to safer food for consumers.

7.0. Food Safety and Inspection Service

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 several comprehensive reports related to the agency's sampling programs. These reports allow FSIS to publicly share information about the agency's sampling programs and discuss the scientific and policy basis for these programs. Data inform the development of new

programs and allow us to modify existing programs, as well as to develop partnerships with Federal agencies, universities, and industry. FSIS-generated data can be found on our website: https://www.fsis.usda.gov/science-data.

FSIS reviews new technologies that establishments 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).

FSIS identifies research gaps and updates its research needs list annually. The agency communicates these research needs to our partners and stakeholders during meetings with agency leadership, through seminars at universities and scientific conferences, and postings on the FSIS website.

In FY 21, FSIS made major changes to the Research Priority website. FSIS reorganized and edited the list of research priorities, and compiled them under four sub-headings:

1. Chemicals of Potential Concern

2. Biological Hazards

3. Animal Welfare

4. Label Verification

FSIS reviewed and edited the list of research studies, removing 30 studies that had been completed. The remaining studies were realigned into data gaps, laboratory methods and longer term research studies. More information and a complete list of current FSIS Research Priorities and Studies is available at:

https://www.fsis.usda.gov/science-data/research-priorities.

In FY 2021, FSIS proposed one new priority and eight new food safety research studies, associated with existing priorities. The new priority includes understanding the source of pathogens and how they contaminate FSIS products preharvest. These new research studies include identifying preharvest sources of *Salmonella*, improving detection methods for Shiga Toxin Producing *E. coli*, improving detection methods for *Salmonella*, developing new rapid detection methods for chemical residues, controlling pathogen growth on beef carcasses, controlling pathogens in offal, determining whether toxins can grow in egg products, and determining whether pathogens that FSIS does not currently test for are of concern.

During FY 2021, the research priorities, data gaps, laboratory methods, and research studies website pages were each accessed on more than 5,200 occasions. Approximately 58 percent of page views were by new visitors, and about 77 percent of visitors were referred by search engines or partner agency websites.

7.3. Activities in FY 2021

Facilitating the Application of New Food Safety Technologies to Food Production

During FY 2021, FSIS evaluated 82 new technologies designed to enhance food safety, including new

commercial pathogen control interventions, process innovations, and the use of new ingredients. FSIS posts brief summaries of the technologies on the FSIS New Technology Table to increase public and industry awareness of available new technologies (New Technology Information Table | Food Safety and Inspection Service (usda.gov).

Guidance for Industry on Safe Food Production

The Agency released 22 guidance documents, including 12 generic HACCP models (Small and Very Small Plant Guidance), guidelines for the control of Shiga Toxin-Producing *Escherichia coli* in beef slaughter and processing operations, guidelines for controlling *Salmonella* and *Campylobacter* in raw poultry, and a guideline on the donation of products to nonprofit organizations. Additional information on guidance documents can be found on the FSIS Guidelines webpage.

Educating Consumers and Other Stakeholders on Science-Based Food Safety

Consumer Engagement: FSIS continued its annual consumer research efforts to gain indepth understanding of food safety behaviors by observing consumers preparing food in a test kitchen. In this observational study, FSIS examined consumers grilling bratwurst and hamburgers and preparing a ready-to-eat (bagged) salad. The Agency included food safety instructions in recipes provided to participants in the experimental group and observed the impact this had on their food safety practices versus the control group. A few key insights include:

- Thermometer use was significantly higher in the experimental groups as compared with the control group for determining doneness of both hamburgers and bratwurst.

- Handwashing attempts before meal preparation were significantly higher in the two experimental groups when compared with the control group. However, for handwashing attempts during the meal prep, there was no significant difference between the groups.

The results offer unique insights into consumer behavior that the Agency would not have been aware of otherwise. The data gleaned from the research is incorporated into consumer food safety messages.

Public Meetings: FSIS hosted a virtual public meeting with participation from the U.S. Food and Drug Administration (FDA), CDC, and the Partnership for Food Safety Education. The event reinforced FSIS's reputation as a modern, 21st century public health organization that uses data to drive outreach and collaboration with partners in Government, industry, and consumer advocacy.

- More than 1,000 industry, consumer representatives, nonprofits, and food safety advocates registered.

- An average of 400 online visitors attended throughout the 5-hour meeting.

- Advocates, academia, Government, and the private sector shared their innovations and research.

- All agreed to share future research.

- Partners agreed to continue collaboration with FSIS.

FSIS held a virtual public meeting of the National Advisory Committee on Meat and Poultry Inspection (NACMPI). The members of NACMPI prepared recommendations on how FSIS should clarify the agency's positions on the custom and retail exemptions to ensure that meat and poultry produced under the exemptions are safe, wholesome, and correctly labeled and packaged. The members also advised on actions FSIS should take to prevent and reduce illnesses associated with the handling or consumption of frozen, raw, stuffed, not ready-to-eat (NRTE) poultry products, which may be breaded and par-fried and may appear ready-to-eat (RTE) to consumers.

FSIS hosted an Analytics Data-Driven Food Safety Conference for employees. This virtual conference showcased the ways that FSIS leverages data to improve food safety and public health. It provided FSIS employees the opportunity to learn more about the innovative and often behind-the-scenes data analysis at FSIS.

FSIS gave multiple presentations at the 2021 International Association for Food Protection Annual Meeting, as listed below:

Category	Title	FSIS Presenters
Symposium	*Listeria monocytogenes* in Deli Meat	Andrea Cote (OPHS) / CDC co-presenter
Round Table Discussion	Are All *Salmonella* Equal? Genomic Approach for Risk Ranking *Salmonella* Strains	Emilio Esteban and Isabel Walls (OPHS)
Technical Talk	*Salmonella* Serotypes From FSIS Samples Linked to Outbreaks	Wu San Chen (OPHS)
Roundtable Discussion	Incentives for Preharvest Control of Zoonoses in Food Animals	Emilio Esteban (OPHS) - panelist
Round Table Discussion	A North American Perspective on Antimicrobial Resistance and Regulatory Action	Uday Dessai (OPHS)
Symposium	FSIS Regulatory Perspective on Evaluating Establishment Support for Product Dispositions	Meryl Silverman (OPPD)

Round Table Discussion	Riding the Tide of Multi-Disciplinary Approaches to Evaluate Behavior-Change Effectiveness of Food Safety Education	Aaron Lavallee (OPACE)
Round Table Discussion	Food Irradiation: Where We've Been, Where We Are Now, and What's Next	Udit Minocha (OPHS) / CDC co-presenter
Technical Talk	Effect of Antimicrobial Interventions on *Salmonella* Percent Positive in Raw Poultry Slaughter Establishments	Selena Kremer-Caldwell (OPPD) / ARS co-presenter
Technical Talk	Developing a New Quantitative Risk Metric Tool to Support Individual Sanitary Measure Equivalence Reviews	Janell Kause (OPHS)
Technical Talk	Assessing Shiga Toxin-Producing *Escherichia coli* in FSIS Regulatory Pork Samples	Maria Scott (OPHS) / ARS co-presenter
Symposium	A Novel Approach to Species Identification in Response to the 2018 Farm Bill	Tye Boynton (OPHS)
Technical Talk	NARMS Expansion Project: Exploring *Salmonella* Isolates From Cattle Lymph Nodes in FSIS	Mustafa Simmons (OPHS)
Technical Talk	Risk Ranking of FSIS Shiga Toxin-producing *Escherichia coli* (STEC) Based on Virulence Genes	Jamie Wasilenko (OPHS)
Technical Talk	Aligning confirmation criteria for *E. coli* O157:H7 and the "top-six" non-O157 Shiga toxin-producing E. coli (STEC)	Michael Day (OPHS)
Symposium	Update on Whole Genome Sequencing Draft International Standard (ISO WG25)	Peter Evans (OPPD)
Symposium	Where's the Beef? Grinding Recordkeeping and Intended Use at Retail	Kristi Barlow (OPHS)/Robert Witte (OPPD)
Technical Talk	Expansion of *Salmonella* Infantis pESI Plasmid to Additional *Salmonella* Serotypes	Glenn Tillman (OPHS)
Symposium	How Foodborne Outbreaks Have Informed FSIS Policy	Kis Hale (FSIS)
Poster	Continued Monitoring of PFAS in U.S. Food Supply	Ivan Lenov (OPHS)
Poster	*Escherichia coli* O157:H7 and *Salmonella* Occurrence in Raw Ground Beef Samples Collected at Retail	Steve Mamber (OPARM)
Poster	Noteworthy Updates and Expansion of the USDA's Food Safety and Inspection Services Accredited Laboratory Program	Sarah Edwards (OPHS)
Poster	Monitoring Environmental Contaminants in Meat, Poultry, and Egg Products	Alexander Domesle (OPHS)
Poster	Annual Sampling Plan and Sampling Summary Reporting at the USDA, Food Safety and Inspection Service	Rebecca Fields (OPHS)
Poster	ARS Studies Addressing FSIS Research Needs	Udit Minocha (OPHS)
	Salmonella Isolates and Antimicrobial-resistance Trends in FSIS Sampling for the National Antimicrobial-resistance Monitoring System (NARMS), 2014–2019	Catherine Rockwell (OPHS)
Poster	FSIS Siluriformes Sampling at Five Years	Wayne Schlosser (OPHS)
Poster	Focus Group Studies on *Listeria* Control at Retail – Outcomes and Next Steps	Kristi Barlow (OPHS)

Poster	Shiga Toxin-Producing *Escherichia coli* (STEC) Recovered from Verification Sampling of Raw Beef Products Collected by the USDA, Food Safety and Inspection Service	Steve Mamber (OPARM)
Poster	Evaluation of Decreased Recalls Recommended by the USDA, Food Safety and Inspection Service in Calendar Year (CY) 2020	Barry Rhodes (OFO)
Poster	One Health Enteric Package v1.0: Expanded and Standardized Metadata for Enteric Genomic Epidemiology in the U.S.	OPHS co-authors Mustafa Simmons and Cesar Morales

CDC = Centers for Disease Control and Prevention, OPHS = CDC Office of Public Health and Science, FSIS = Food Safety and Inspection Service, OPPD = FSIS Office of Policy and Program Developmen, OPACE = FSIS Office of Public Affairs and Consumer Education, OPARM = FSIS Office of Planning, Analysis and Risk Management, and OFO = FSIS Office of Field Operations.

Agency Communications: In FY 2021, FSIS focused on improving the Agency's digital communications, including redesigning its public website (www.fsis.usda.gov) and working to increase email subscriptions to food safety related topics. The redesign of the website brought FSIS into compliance with the U.S. Web Design Standards and the USDA Digital Playbook, meeting website modernization goals and improving access to food safety information. Consumer research heavily informed the design of the new website, creating easy to use food safety recall pages, increasing plain language usage throughout the site, and organizing information based on user models verses organizational charts and reporting structures. The new site leverages a cloud-based, modern content management system, laying the foundation for future innovation and site improvements. The new site significantly improved accessibility by using updated code and templates that are 508 compliant. Many requesters ranging from the media, special interest groups, industry, consumer groups, as well as people in academia seek information provided on our website.

Social Media\Outreach: FSIS continued to work closely with those at FoodSafety.gov to promote content on the cross-Federal, consumer-focused website. FSIS also used a variety of social media

networks to broaden engagement with key stakeholders to educate the public on recalls, foodborne illness, and safe food handling practices. FSIS' FoodKeeper application remains a relevant, useful and effective way to educate consumers about proper food storage and its relationship to safe food handling behaviors. Currently, the app offers storage and food safety guidance on more than 650 foods and beverages. More than 31,000 downloads of the application this fiscal year brought cumulative download totals of the application to 337,000 since its launch in April 2015.

Transferring Analytical Methods Development to FSIS Laboratories

The FSIS Field Service Laboratories support the mission of the FSIS to protect public health by performing analyses of samples collected from meat, poultry, Siluriformes, and egg products. In 2021, the laboratory system completed five comprehensive method updates: four microbiology methods and one chemistry method. These can be found on our website:

Microbiology Methods:

MLG 1.01: [FSIS Laboratory System Introduction, Method Performance Expectations, and Sample Handling for Microbiology](#)

MLG 5C.02: [Detection, Isolation and Identification of Top Seven Shiga Toxin-Producing *Escherichia coli* (STECs) from Meat Products and Carcass and Environmental Sponges](#)

MLG 20.00: [LCD-Macroarray Method for Species Identification in Meat and Poultry Products](#)

MLG 41.06: [Isolation and Identification of *Campylobacter jejuni/coli/lari* from Poultry Rinse, Sponge and Raw Product Samples](#)

Chemistry Method:

CLG-PFAS2: [Screening, Determination and Confirmation of PFAS by UPLC-MS-MS](#)

Maintaining and Updating 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 (MTAs). In 2021, FSIS completed 14 MTAs, with Government partners, industry, and academia.

Material Transfer Agreements completed in 2021

Bacterial isolate	Industry, Academia or Federal Partner
Turkey *Salmonella*	Government Partner
Cecal samples	Academia
NARMS Cecal-Lymph Node data	Academia
Salmonella Kentucky	Government Partner
Salmonella Kentucky isolates	Academia
Salmonella	Academia
Autogenous Vaccine *Salmonella*	Industry
Campylobacter strains	Industry
Salmonella	Government Partner

Salmonella outbreak strains	Industry
Salmonella Infantis	Government Partner
Autogenous Vaccine	Industry
Listeria monocytogenes and *Salmonella*	Academia
Salmonella Minimum Inhibitory Concentration data	Government Partner

8.0. National Agricultural Statistics Service (NASS)

8.1. Mission Statement

"The USDA, 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 United States.

  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. After the season's full conclusion, county-level yield estimates for corn and soybeans are generated by integrating MODIS Land Surface Temperature (LST) products through modeling.

Small area models have been developed to improve the county-level estimates of acreage, yield, and production. In FY 21, models for all crops with federally mandated reporting requirements were implemented for the 2020 crop year. Measures of uncertainty were published with 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 was developed based on annual data collection and implemented in 2021. An improved small area model was developed and implemented for the agricultural labor program. NASS has worked collaboratively with outside consultants to develop these models.

New tools and improvements for monitoring climate anomalies and extreme events for the conterminous States were implemented in NASS's decision support application. An advanced-map tool allows users to create climate variable maps covering a user-specific time interval. The Extreme Weather Alert (EWA) tool systematically monitored climate indicators and alerted when climate anomalies were detected in regions of interest in 2021. In combination with other monitoring tools, the EWA tool began facilitating the analysis and interpretation of potential weather-related impacts over major-producing areas. An effort is underway to combine crop phenology, climate variables, crop simulation indicators, and vegetation indices using machine learning for cotton yield estimation.

- **Revisions in the 2021 June Area Survey:** The COVID-19 pandemic has had a major impact on data collection. In 2020, NASS did not conduct the June Area Survey (JAS), which had always collected data through face-to-face interviews. Given the on-going nature of the pandemic, NASS made the decision to revise survey processes so that it could collect data using telephone interviews (no face-to-face interviews) for the 2021 JAS. Consequently, the JAS process was reviewed, and numerous modifications were made, including a revision of the JAS questionnaire; the creation of a pre-prescreening tool (PPT), which provided maps and administrative and other data useful for identifying the current operator associated with fields in the sample; new data collection procedures; and adoption of a new editing system. These changes contributed to reduced reliance on paper, less need for express shipping, and more interaction with administrative data. In FY 22, the impact on data quality will be assessed.

- **Automated Stratification for Construction of Area Frame:** NASS uses its area frame both as a standalone 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, Ohio, and Puerto Rico have been created using a hybrid stratification approach that uses 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 the case with all list frames for complex populations, the NASS list

frame is not complete; that is, not all farms are on the list. This lack of completeness has significant implications for the quality of survey data and the official estimates. NASS has examined the practice of web-scraping techniques to identify farms, especially the nontraditional agricultural operations, to measure the undercoverage of the NASS list frame. NASS has collaborated 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 that are not well covered by the NASS list frame, such as urban farms, operators of farmers markets, and local food producers. NASS, in collaboration with the USDA Agricultural Marketing Service, published estimates from the Farmers Markets Managers Survey; a web-scraped list frame and a voluntary business register of farmers market managers were used to assess the undercoverage of each list using a capture-recapture framework and a composite estimator.

NASS has been developing the capacity to conduct web scraping. In FY 21, two web-scraped list frames of hemp farms were created, one by MACE and the other by NASS. In FY 22, these will be used to assess undercoverage in the AMS list of licensed industrial hemp growers during the Hemp Acreage and Production Survey, a joint effort between NASS and AMS. In addition, the quality of the two web-scraped list frames will be compared to each other and the AMS list.

- **Geospatial Products:** NASS completed its 48-State Cropland Data Layer (CDL) in 2021 for the 2020 crop year, making 13 years of national CDLs 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. In FY 21, NASS collaborated with the USDA Agricultural Research Service (ARS) to modernize the publicly available end-of-year CDL, which is now published on a web portal as CroplandCROS in the USDA cloud.

NASS continued to provide its 48-State VegScape, which is a geospatial data service offering automated updates of vegetative condition at daily, weekly, and biweekly intervals. The 48-State Crop Frequency Layers were released in 2021 for the 2020 crop season. The Crop Frequency Layers identify crop specific planting frequency and are based on land cover information derived from the 2008 through 2020 CDL. Currently, these are produced for corn, soybeans, wheat, and cotton.

NASS, in collaboration with NASA and the USDA, Agricultural Research Service (ARS), developed a geospatial product, 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.

Geospatial decision support products were derived and provided for rapid response to assess flooded areas and identify potential crop losses caused by early season flooding in the Mississippi Delta region, late season flooding from Hurricane Ida, and the prolonged western drought and extreme heatwave event from early July through August 2021. The geospatial data products were derived from remotely sensed satellite and meteorological information obtained

from the NASS Climate-Based Information System, the NASS Crop Condition and Soil Moisture Analytics (Crop-CASMA) Program, the PRISM Climate Group, and the National Oceanic Atmospheric Administration (NOAA) National Hurricane Center. Cropland disaster assessments were shared with the USDA Operations Center Emergency Programs Division and the USDA Office of the Chief Economist to be included in their mapping efforts. The disaster assessment reports, maps, crop inundation raster layers, metadata, and a methodology report have 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 website 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 and, during FY 19, all NASS surveys were moved into the new system. During FY 20, NASS worked closely with producers to modernize areas of its data collection efforts and to make responding to surveys easier and less time consuming. In FY 22, producers will help test these new capabilities and assist NASS's efforts to ensure that future survey and census data remain as accurate as possible. 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. NASS would not be able to supply valuable agricultural data without producer participation.

The COVID-19 pandemic had major impacts on NASS data collection processes. Face-to-face interviews were discontinued, and the call centers, which were staffed with telephone

enumerators, were closed. NASS quickly revised its data collection approaches, such as decentralizing the data collection centers' phone enumerators by providing iPads to enumerators so that they could collect data from their residences. For the safety of field enumerators who traditionally collect data through face-to-face interviews, their data collection method shifted primarily to telephone interviews as well. To encourage mail and web responses, pressure sealed envelopes, with an encouraging message to respond online and with the requisite EDR code to do so, were mailed. This mailing effort may be at least partially responsible for the observed increase in mail and web responses. In FY 22, the long-term approach to data collection will be considered.

- **Respondent Portal:** Development of a new respondent portal was initiated in FY 21. Designed based on producer feedback and focus sessions, the new portal will provide respondents the ability to continue to respond safely and securely to current surveys electronically. New functionality will allow one to view localized weather data, data visualizations, and field maps with associated information, and easily find the most popular NASS reports. An optional eAuthentication login account will offer producers the ability to see upcoming surveys, view historic responses, and complete surveys. An online feedback feature will allow for continued improvements based on customer experience. The portal should be available for all surveys in FY 22. Additional features will be added in subsequent years as funding allows.

- **Modernization of Data Dissemination:** NASS has traditionally provided information to the public by posting on the web, its published reports and aggregated survey data in Quick Stats. To enhance the usability of the information, NASS is developing a new data dissemination process that focuses on a subject area, such as dairy, and offers easy access to and visualization of

relevant information. In FY 21, the database and user interface foundation were completed with the support of a contractor. The public-facing dairy and economics landing pages will be introduced in FY 22 with additional subjects coming in subsequent years.

- **Integrating All 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, administrative data, remote sensing estimates, and weather information. The Agricultural Statistics Board combines this information using expert opinion to produce official estimates. NASS initiated a pilot study in Illinois to explore the use of all available data, including survey, remote sensing, administrative, weather, and precision agriculture data, to produce early season estimates of planted acreage. To support that effort, in FY 21, NASS established a high-performance computing environment in the USDA EDAPT environment and began automating the collection and integration of these diverse data. Further progress in automation is planned for FY 22.

In FY 21, modeled inseason estimates of planted acres of corn and soybeans, based on all available data, were produced for the pilot State of Illinois and provided to the NASS Agricultural Statistics Board. As part of the effort to geo-reference farms in Illinois, farms were added to the NASS list frame, thereby improving its coverage. A Predictive Cropland Data Layer (CDL) was created in March, which is 3 months earlier than the traditional approach. This Predictive CDL was used in the editing and imputation processes of the June Area Survey. A new geospatial product, the Crop Sequence Boundaries (CSB), which developed collaboratively with the USDA Economic Research Service, provides agricultural field polygons, including their crop pattern rotation history, for the conterminous United States. Its uses include serving as a

foundation for modeling, improving coverage of the NASS list frame, and facilitating georeferencing of farms. In FY 22, modeling efforts will be expanded to those States with the largest corn and soybean production; farms in the States with the largest corn, soybeans, wheat, and cotton production will be georeferenced; and planning efforts will begin to integrate the new products into the production process.

- **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. Experiments assessing the potential impact of the use of PRD were conducted within the 2020 September Agricultural Production Survey (APS) showed no signs of a reduction in data quality with the use of PRD. Proof-of-concept tests were conducted in the 2020 September APS and the 2020 Census of Agriculture Content Test. No negative impacts on data quality were identified in the 2020 September APS. Although the analysis of the 2020 Census of Agriculture Content Test is ongoing, respondents had very positive feedback on having PRD available, indicating a reduction in perceived burden. PRD was provided to all respondents for whom it was available in the 2021 June APS, representing the first time PRD was fully automated on the web instrument and included as part of the production process. The 2021 Census of Agriculture Web Only Test is to be conducted in early 2022. If the results continue to indicate that PRD can be provided without harming data quality, then PRD will be used in more NASS surveys and the Census of Agriculture beginning in 2022. Contractors facilitated the development of the PRD automation system in FY 21 and will continue to refine the system in FY 22 in preparation for the 2022 Census of Agriculture.

- **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 explored approaches to automating editing and imputation processes while improving data quality. In FY 21, portions of the process were automated, and a contract was established to create a generalized edit and imputation system. In FY 22, a working prototype is to be developed for the Agricultural Production Surveys and the County Estimates Surveys. 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 2021 Data Users' Meeting were held virtually on April 14-15 and October 13–14, 2021. It 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.

8.5. Publications

Peer-Reviewed Scientific Publications ....15 entries

- Zhang, Chen et al. (2021). Rapid in-season mapping of corn and soybeans using machine-learned trusted pixels from Cropland Data Layer. *International Journal of Applied Earth Observation and Geoinformation*, Volume 102, October 2021, 102374. https://doi.org/10.1016/j.jag.2021.102374.

- Diao, Chunyuan et al. (2021). Hybrid phenology matching model for robust crop phenological retrieval. *ISPRS Journal of Photogrammetry and Remote Sensing,* Volume 181, November 2021, pages 308–326. https://doi.org/10.1016/j.isprsjprs.2021.09.011.

- Fabbri, P. et al (2020). Subsoil Reconstruction in Geostatistics beyond Kriging: A Case Study in Veneto (NE Italy). *Hydrology*, Volume 7, Number 1, page 15.

- Hyman, M. et al. (2021). Capture–Recapture Estimation of Characteristics of U.S. Local Food Farms Using a Web-Scraped List Frame. *Journal of Survey Statistics and Methodology*.

- Johnson, David and Richard Mueller (2021). Pre- and within-season crop type classification trained with archival land cover information, *Remote Sensing of Environment*, Volume 264, 112576, https://doi.org/10.1016/j.rse.2021.112576.

- Liu, P. et al. (2021). Assessing disaggregated SMAP soil moisture product in the United States. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, Volume 14, January 2021, pages 2577-2592, https://doi.org/10.1109/JSTARS.2021.3056001.

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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 capacity grants to land-grant universities and competitive grant funding to eligible universities and organizations.

- 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, communities and others.

NIFA has working partnerships with many institutions, associations, and members of the research and extension communities. Our key partners are the institutions in the Land-Grant University System, other U.S. nonland-grant universities, nonprofit organizations, and small businesses. NIFA also offers multiple grants in research, education, and extension that benefit minority-serving institutions. Partnerships among land-grant and nonland-grant institutions and organizations strengthen program developments and resources. These have resulted in culturally appropriate innovative research,

education, and extension nutrition and health-enhancing programs. NIFA partners with other Federal agencies within and beyond USDA such as nonprofit associations, professional societies, commodity groups and grower associations, multistate research committees, private industry, citizen groups, foundations, regional centers, the military, taskforces, and other groups.

NIFA provides Agriculture and Food Research Initiative grants to support research, education and extension activities in the six Farm Bill priority areas: plant health and production and plant products; animal health and production and animal products; food safety, nutrition, and health; bioenergy, natural resources, and environment; agriculture systems and technology; and agriculture economics and rural communities. 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 USDA's Strategic Goals: containing the COVID-19 pandemic; ensuring racial justice and equity; ensuring food and nutrition security; rebuilding the rural economy; and addressing the impacts of climate change. 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 sustainable agricultural system responsive to environmental, economic, and societal needs as climate change is addressed.

- 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 extension offices in each community throughout the Nation and U.S. territories. Extension educators respond to public inquiries and conduct workshops and other educational events.

Moreover, with support from more than 500,000 volunteers, 4-H—USDA's 119-year-old youth development program administered through NIFA and Cooperative Extension—serves more than 6 million young people every year and teaches life skills through hands-on learning, leadership and positive youth development.

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. 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.

Many land-grant universities funded by NIFA have a 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, noncredit educational network. These offices provide useful, practical, and research-based information to agricultural producers, small business owners, youths, consumers, and others in rural areas and communities of all sizes.

9.4. Strengthening Current Activities and New Initiatives

NIFA administers the USDA Small Business Innovation Research (SBIR) program. In FY 2021 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 tiebreaker 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 patent applications for CRADA partners and charges the partner only 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 FY 21, USDA SBIR awarded 12 CRADA proposals across the program's 10 topic areas.

Since FY 2018, NIFA's AFRI Sustainable Agricultural Systems (SAS) Program has encouraged partnerships in research and implementation through research, extension, and education integration to help transform the U.S. food and agricultural systems. During the first 3 years of the program, 30 Coordinated Agriculture Projects (CAPs) were awarded $290 million 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 translation of foundational research into applied research and product development that provides impact and adoption of technology solutions. In FY 2021, AFRI SAS added five additional projects to the previous five CAPs that incorporate collaborations with organizations involved in adoption, technology implementation, and/or commercialization. These FY 2021 projects address challenges that are substantially positioned for rapid transfer of technology, knowledge, and data. Projects included are: developing value chain diversity through transition to on-farm resilient agronomic intensification, expanding domestic aquaculture through enabling sustainable U.S. aquaculture and food systems, developing new adoptable techno-economically viable cultivated-meat systems and educational platforms for training future professionals, and another project focused on the development and transfer of climate resilient water tools and techniques to improve decision making for growers and water managers.

9.5. Response to Presidential Memorandum on Accelerating Technology Transfer and

Commercialization of Federal Research in Support of High-Growth Business

New Metrics (beginning FY 2014) on NIFA outcomes:

Efforts to develop procedures for requesting information from NIFA awardees continue. A survey of past SBIR Phase II winners from 1994 through 2015 was conducted in 2018. Analysis of responses for the survey will be completed in FY 2022 by the University of Nebraska-Lincoln Methodology and Evaluation Research Core (MERC). 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. In addition, UNL MERC will manage the administration of the next survey.

The data on the patents issued based upon competitive NIFA funding has been collected for FY 2021 (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 FY 2021 Based Upon Competitive NIFA Funding.

Institution Name	Award Number	Patent Number	Issue Date	Invention Description
UNIVERSITY OF MASSACHUSETTS AMHERST	2016-67017-24458	10921257	2/16/2021	Method and System of Pesticide Detection Using Sers
UNIVERSITY OF MASSACHUSETTS AMHERST	2016-67017-24458	10942124	3/9/2021	Surface Enhanced Raman Scattering Substrate Assembly

UNIVERSITY OF WISCONSIN-MADISON	2006-35503-16998	10945448	3/16/2021	A Process for Removing Phospholipids and Off-Flavors from Proteins and Resulting Protein Product
UNIVERSITY OF WISCONSIN-MADISON	14-CRHF-0-6055	10968425	4/6/2021	Global Gene Regulators (GGR) as Vaccine Candidates Against Paratuberculosis
WASHINGTON STATE UNIVERSITY	2019-31100-06053	PV202000261	4/9/2021	WA8268 'Scorpio' Hard Red Winter Wheat
COLORADO STATE UNIVERSITY	2019-34141-30433	PV0006414	4/19/2021	AAC Shirley
UNIVERSITY OF MINNESOTA	2014-67009-22305	10988772	4/27/2021	Low Glucosinolate Pennycress Meal and Methods of Making
UNIVERSITY OF WISCONSIN-MADISON	06-CRHF-0-6055	10995342	5/4/2021	RGH1 Mediated Resistance to Soybean Cyst Nematode
UNIVERSITY OF MINNESOTA	2016-67021-24534	11004262	5/11/2021	Semantic Structure from Motion for Orchard Reconstruction
UNIVERSITY OF MINNESOTA	2016-70006-25828	11003908	5/11/2021	Remote-Sensing-Based Detection of Soybean-aphid-Induced Stress in Soybean
UNIVERSITY OF CONNECTICUT SCH OF MED/DNT	2010-33522-21697	11008581	5/18/2021	Elevated Auxin and Reduced Cytokinin Contents in Rootstocks Improve Their Performance and Grafting Success
UNIVERSITY OF WISCONSIN-MADISON	17-CRHF-0-6055	11028402	6/8/2021	Polypeptide and Yeast Cell Compositions and Methods of Using the Same
UNIVERSITY OF WISCONSIN-MADISON	2016-33610-25444	11027975	6/8/2021	Method to Make Phosphoric Acid and Ammonium Phosphates from Phosphate Minerals
UNIVERSITY OF NEBRASKA LINCOLN	2013-67021-20947	11045672	6/29/2021	Fire Suppression and Ignition with Unmanned Aerial Vehicles

LOUISIANA STATE UNIV A&M COL BATON ROUGE	2015-67015-23277	11083787	8/10/2021	Bovine herpesvirus type 1 (BoHV-1) vector against bovine respiratory disease complex
UNIVERSITY OF WISCONSIN-MADISON	18-CRHF-0-6055	11091844	8/17/2021	Method to Make Flexible, Free-Standing Graphene Paper and Product Formed Thereby
UNIVERSITY OF WISCONSIN-MADISON	12-CRHF-0-6055	11096382	8/24/2021	Methods and Compositions for Determining Bovine Ovulation Rate

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 to promote the technology transfer and utilization from foundational research.

(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 FY 2022 and FY 2023 (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 detection and diagnostics of transboundary, emerging, or re-emerging pests and diseases associated with animal

production systems and/or transboundary, emerging, re-emerging, and invasive diseases, insects and weeds associated with plant production systems.

(2) Coordinate APHIS regulatory and ARS research efforts with relevant components of the Cooperative Extension Service to better identify producer needs and the transfer of relevant technology.

For nearly 20 years, NIFA and ARS have conducted stakeholder workshops at least every 5 years as part of the ARS 5-year review of ARS National Programs. In FY 2020, ARS conducted a 5-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 contribute. More than 500 stakeholders provided comments. In FY 2021, ARS conducted a 5-year review of the ARS NP101 Food Animal Production program. ARS used an online survey and NIFA ensured that faculty at land-grant universities had opportunities to participate.

Over 570 stakeholders provided responses to this survey. In addition, in January 2021, ARS and NIFA administrators co-led several webinars to collect stakeholder input. NIFA will use the results from these coordinated activities with ARS to inform priorities for future NIFA competitive grant programs, including programs that will address producer needs and programs that support extension activities to transfer knowledge and technology developed from research projects to producers. With specific regard to aquatic animals, in 2018, ARS conducted listening sessions to inform the 5-year review of NP106 Aquaculture. Likewise, in 2020, ARS, NIFA and eight other USDA agencies conducted seven coordinated "Deep-Dive" listening sessions with aquaculture stakeholders around the United States, culminating in the publication of a white paper titled: "Aquaculture is Agriculture: USDA's Role in Supporting Farmers of Fish, Shellfish, and Aquatic Plants." Lastly, USDA and NOAA coordinate

interagency aquaculture activities through the NSTC Subcommittee on Aquaculture and its Task Forces. The subcommittee is currently incorporating stakeholder comments to drafts of the National Aquaculture Regulatory Efficiency Plan, The National Strategic Plan for Aquaculture Research, and the National Aquaculture Economic Development Plan. Through the SCA, USDA leads a special project to solicit Federal input on the National Aquaculture Health Plan and Standards.

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

Windcall Mfg. Inc had a goal to replace the full-sized combine with a hand-held combine/sampler for moisture testing small grains. The USDA SBIR Phase I grant resulted in purchase of materials, hire of machine tooling, and pay for CAD drawings which resulted in a functioning prototype, called "Grain Goat." This prototype proved the feasibility of the product and outperformed expectations. The prestige and credibility of being a SBIR grant recipient validated both the product and company. As a result of the media publicity from the grant, Windcall Mfg. was able to secure additional funding through State

grants and Angel investors. Because of Grain Goat, Windcall Mfg. was named Innovative Business of the Year by the Nebraska Business Development Center. Having successfully completed the USDA SBIR Phase I grant goals, Windcall Mfg. applied for and received a Phase II grant which allowed moving the functioning prototype to a retail-ready machine that was demonstrated in the field. This grant money helped Windcall develop Grain Goat beyond proof of concept, expanding the technology to farmers and seed researchers. Input from these stakeholders helped to streamline the Grain Goat into a lighter weight, yet more efficient machine. The notoriety from the grants resulted in working with Agrotronix to use their moisture meter on the Grain Goat. Furthermore, Windcall Mfg. was invited to apply for the Farm Bureau Entrepreneur Challenge and became one of the top three finalists in the Nation.

A goal of En Solucion is to validate the effectiveness of a high concentration ozone nanobubble solution at improving the productivity, quality, shelf-life, and safety of apple crops when integrated into postharvest wash processes. Due to the increasing specialization of the apple industry, devastating brand damage can result from negative consumer events such as a foodborne illness, recalls, decreased quality, and premature decay and spoilage in new apple varieties. The technology developed under USDA SBIR Phase I and II funding offers a cost-competitive, more effective alternative to the current postharvest wash methods resulting in reducing or eliminating pathogens and other field-acquired contaminations that can result in foodborne illness outbreaks or fungal infections that impact shelf-life. En Solucion's technology is being developed to install directly into existing packing lines and uses ozone nanobubble-infused water to wash apples as a spray to the surface of the product or directly to the wash water in which the product is immersed. The high concentration ozone nanobubble wash water can destroy bacteria and other harmful pathogens on the surface of the product and in the wash water, effectively preventing cross-contamination. The ongoing SBIR Phase II funding will validate the effectiveness of

ozone nanobubbles as a postharvest intervention for apples through a series of microbial experiments and pilot farm demonstrations that measure the impact of ozone nanobubbles on pathogen neutralization. Development and transfer of the technology through licensing to post harvest industries will ultimately lead to the production of innovative technology with the potential to make fresh tree and pome fruits safer in a way that is more effective, cost-competitive, and better for workers and the environment.

USDA SBIR Phase I award to Halomine Inc. led to a $30,000 private equity investment from Launch NY at the end of 2019. As the pandemic started, Halomine continued to make significant progress in concept validation during 2020, joining the Indie Bio incubator (sponsored by the SOSV venture capital firm) and Plug and Play accelerator, raising over half a million dollars from investors, and over $300,000 in awards from business plan competitions. Partially because of the advances made during the USDA Phase I work on food safety, Halomine also received two NSF Phase I SBIRs focused on virus efficacy and institutional settings, and one NIH Phase I SBIR focused on hospitals and reducing hospital acquired infections. Halomine's first product, HaloFilm, is a spray-on product that dries and leaves an ultrathin, durable, transparent film on a surface. The film is a polymer composed of one monomer that sticks to the surface, and another monomer that stabilizes chlorine. HaloFilm, essentially a chlorine extender, relies on the efficacy of chlorine, which has decades of use and broad-spectrum efficacy against pathogens without generating pathogens with resistance. The USDA SBIR Phase II award to Halomine has supported deeper investigations into production and product performance testing which ultimately enabled the company to attract Diversey, a $2.7 billion global industrial cleaning and infection control company, as a corporate partner. Halomine, Inc continues to execute on our Phase II to support efforts to bring this food safety product to market along with translating technology in other consumer and health fields. The Diversey relationship will significantly expand the immediate reach for

commercial entry and potentially have a significant impact on food safety for consumers in the United States and worldwide.

The SBIR grants awarded to Applied Food Technologies (AFT) a privately held company aimed to develop a rapid device for the identification of samples that could distinguish among the major tuna species as well as common tuna adulterants (e.g., escolar). During the course of the USDA SBIR Phase 1 and Phase 2 awards, AFT was able to develop simple, easy to use lateral-flow based identification methods. The final method, Tuna-Sticks™, can determine whether tuna (and which tuna species) is present in processed fish samples. This is a critical tool to support expansion of sustainable harvest and aquaculture production of large pelagic tuna species. Recently, AFT has begun using Tuna-Sticks™ in collaboration with Chicken-of-the-Sea and Eurofish to confirm sustainability criteria of their 100 percent Skipjack products. Likewise, AFT recently used their process to verify the presence of tuna in samples of Subway sandwiches for the television show Inside Edition.

A new weed seed killing device developed by Global Neighbor Inc. (GNI) mounts inside combines uses a blend of heat and intense blue light to destroy weed seeds before they exit the combine. The concept for this device was the result of the company founder's (Jon Jackson) desire to find chemical-free weed control. Development has reached the prototype stage. In germination chamber tests at Ohio State University, only 8 out of 1,200 treated Palmer Amaranth (pigweed) seeds grew compared to 97 percent of untreated control seeds. This device consists of an auger through which seeds and chaff pass before exiting the combine. The diameter and speed of the auger determines the volume of material the Weed Seed Destroyer can handle. A heating unit warms the seeds and chaff before they pass through blue light from LED bulbs. This process kills more than 95 percent of the seeds immediately. The remaining 5 percent remain alive but are unable to germinate. During the fall of 2021, the Weed Seed Destroyer will

be installed on a combine in Tennessee, and test units will be in Ohio and Louisiana. GNI plans to sell 10 to 15 systems next year and then scale up to more than 100 units in 2023.

Membrane Protective Technologies Inc. worked to develop the extender Gamete Guard™ to provide protection to sperm cells during the cooling, freezing, and thawing processes for artificial insemination. Gamete Guard™ reduced DNA, membrane, and acrosome damage by an average of 15–30 percent in frozen/thawed bovine sperm resulting in an increase in pregnancy rates in dairy cows. This technology will provide a cost-effective option to decrease economic losses, improve fertility, and increase food production for a growing population.

Cambridge Technologies LLC successfully developed a universal swine influenza A virus (IAV) vaccine with high efficacy for pigs in the United States. Swine influenza A virus causes acute respiratory disease in pigs and is a high priority for animal health. Multiple subtypes of IAV are responsible for annual outbreaks of IAV, with increasing evidence suggesting that IAV has moved from seasonal infections to being endemic year-round in swine herds. The vaccine that Cambridge Technologies LLC developed for swine production systems is crucial to limit the losses due to IAV.

Stony Creek Colors, Inc. (SCC), a dye manufacturer based in Springfield, TN, envisions a vibrant fashion industry that values clean and natural colors used as a source of restoration, bringing life to the places it's grown, dyed with, and worn. SCC partners with local farms to grow indigo as a regenerative rotational crop that improves profitability and ecosystem health for farmers. The company's vertically integrated model then allows the implementation of safe and transparent extraction processes in U.S.-based production. Stony Creek collaborates directly with customers, values-driven textile mills, and fashion brands to reach industrial scale and bring naturally dyed products to consumers globally. SCC

manages all aspects of the natural indigo supply chain—from seed genetics, to crop production, to chemical extraction, to supporting industrial dyers, and developing new dye applications. The company has developed a proprietary dye production method which allows for high-yield high-purity natural indigo dye to be safely and sustainably produced from indigo crops sourced from sites across the Southeast United States. USDA-NIFA SBIR Phase I and II funding provided support for Stony Creek's efforts in proving the business fundamentals, building out the farm-to-market supply chain, and most recently, developing major innovations in the company's ability to produce high-quality, high-purity, BioPreferred[TM] natural indigo dye from a storable shelf-stable biomass unlike any previous indigo production process. This has in turn allowed SCC to greatly expand the geography from which the company sources its crops, operate its dye production factory year-round, and place U.S.-grown natural indigo into jeans from brands like Levi's, Wrangler, and Patagonia.

CoverCress Inc. is working to commercialize its varieties of the winter hardy cover crop field pennycress to be grown in corn-soy rotations in the Midwest. CoverCress has been awarded two Phase I awards and a Phase II award by the SBIR 8.2 Plant Production and Protection (Biology) Program. These awards have supported and continue to support the development of new varieties of field pennycress which have disease resistance or altered protein content for use in plant-based protein products. CoverCress states pennycress has approximately 2x the oil concentration of soybean and less than 4 percent saturated fat concentration, and they estimate the cover crop has a potential value of $200–300 per acre. In addition to economic impacts, cover crops have a positive impact on the environment and play an important role in sequestering carbon and protecting soil health. During Phase I funding, CoverCress developed two classes of plant defensins with different modes of action to engineering broad-spectrum disease resistance in pennycress.

HiveTech Solutions is a woman-owned company working to improve honeybee health. HiveTech Solutions was awarded Phase I and Phase II awards by the SBIR 8.2 Plant Production and Protection (Biology) Program. Through these awards, HiveTech developed a Mobile Indoor Climate Controlled Apiary (MICA) for the health needs of honeybees and for the performance needs of beekeepers. MICA is a mobile temperature, CO2, and humidity-controlled apiary. During Phase I, HiveTech found that controlled-climate indoor overwintering could help control Varroa mites, a significant honeybee pest. Honeybee colonies that were overwintered in their MICA were significantly more likely to survive the winter than colonies we left outside. HiveTech worked with Texas, Colorado, Minnesota, and Washington beekeeping partners to test overwintering as well as USDA ARS to construct and optimize the MICA to bring the product to market.

Green Heron Tools' HERgonomic® Shovel-spade, also known as HERShovel™, is the first agricultural tool in the world scientifically designed to be ergonomic for women. Developed with a USDA SBIR Phase I grant, HERShovel™ comes in three sizes to match user height. Other features include light weight (under 4 1/2 pounds); an enlarged, nonslip step to capitalize on lower-body strength and provide stability, comfort and digging ease; and a patented ergonomic textured grip, providing greater comfort and control and allowing for two-handed digging. HERShovel™ is made entirely in Pennsylvania and includes a 10-year warranty. Since its debut, HERShovel™ has earned enthusiastic reviews from customers and been featured in numerous national media, including *ModernFarmer.com*, *The New York Times*, *Mother Earth News*, *The Progressive Farmer*, *Organic Gardening,* and many others. The shovel is available on www.greenherontools.com, which also features tips on healthy digging and general injury prevention. Using funding from USDA NIFA Phase I and II SBIR grants, Green Heron Tools also designed equipment to minimize the health risks of lifting and carrying heavy materials, a prominent cause of musculoskeletal disorders (MSDs) among women livestock farmers and other women farmers

and gardeners. One example is a three-wheeled wheelbarrow, which offers several important health, safety and ease-of-use advantages over traditional wheelbarrows such as increased stability, maneuverability especially in turning, lightweight, and ergonomically friendly.

Prairie AquaTech LLC is a small business based in South Dakota with a global mission of making better ingredients for better feed and food. It is one of the few companies in the world to produce an alternative protein ingredient at commercial scale, with 30,000 tons of its SBIR and industry award-winning Microbially-Enhanced Protein™ or ME-PRO® produced from U.S. soy and shipped all over the world. The USDA SBIR program supported advancement of Prairie AquaTech's microbial enhancement platform technology to include high protein dried distillers grain (HP-DDG) and canola meal as important feedstocks of the future. These projects helped establish the company's unique value proposition of increasing the bioavailability of nutrients in sustainably sourced feedstocks to improve animal health and reduce the environmental impact of animal feeds. Prairie AquaTech has received several patents on these novel, high-quality ingredients and is working with strategic partners to expand its production capacity given the global market demand for protein, specifically in aquaculture and terrestrial animals, including dogs and cats.

9.7. Outreach Activities

NIFA-supported 1890 Land-Grant Institution Outreach

The 1890 Land-grant Institutions (1890s) are Historically Black Colleges and Universities designated as LGUs in the Second Morrill Act of 1890. NIFA's 1890s programs are intended to strengthen research,

extension, and teaching in the food and agricultural sciences by building the institutional capacities of the 1890s.

The 1890 Land-grant System includes 19 universities: Alabama A&M University, Alcorn State University, Central State University, Delaware State University, Florida A&M University, Fort Valley State University, Kentucky State University, Langston University, Lincoln University, North Carolina A&T State University, Prairie View A&M University, South Carolina State University, Southern University, Tennessee State University, Tuskegee University, University of Arkansas Pine Bluff, University of Maryland Eastern Shore, Virginia State University, and West Virginia State University.

NIFA administers a number of 1890 grant programs that support projects that strengthen teaching, research, extension, and facility programs:

- 1890 Institution Teaching, Research, and Extension Capacity Building Grants program that strengthen teaching and research programs in the food and agricultural sciences through cooperative linkages with Federal and non-Federal entities.

- Evans-Allen 1890 Research Formula program that supports basic and applied research at the 1890 institutions in the food and agricultural sciences.

- 1890 Extension Capacity program that supports extension education programs that respond to the changing needs of limited-resource clientele.

- 1890 Facilities Grant program that provides funds for the acquisition and improvement of agricultural and food sciences facilities and equipment, including libraries, so that the institutions may participate fully in the production of human capital in the food and agricultural sciences.

- 1890 Scholarships program is intended to provide scholarships to support recruiting, engaging, retaining, mentoring and training of undergraduate students at the 1890s. The scholarships are intended to encourage outstanding students at 1890 institutions to pursue and complete baccalaureate degrees in the food and agricultural sciences and related fields, leading to a highly skilled food and agricultural systems workforce.

- 1890 Centers of Excellence (COE) program was established in 2015 in conjunction with the 125th Anniversary of the Second Morrill Act of 1890. The 1890 COEs goals are to: (1) increase profitability and rural prosperity in underserved farming communities; (2) address critical needs for enhanced international training and development; and (3) increase diversity in the science, technology, engineering, agriculture and mathematics pipeline.

Program staff annually conduct outreach support to the 1890s through listening sessions with deans and directors, quarterly call meetings that include other representatives of the 1890s, grantsmanship workshops, post-award activities (e.g., presentations at annual meetings and conferences targeted toward minority-serving institutions), representation in peer review panels, enhancing partnerships with other USDA agencies in support of 1890s, and media releases to highlight impacts within the 1890s. Through Federal funding and leadership for research, education, and extension programs, NIFA focuses on investing in science and solving critical issues impacting people's daily lives and the Nation's future.

In 2021, new outreach activities were organized at two HBCUs, Tuskegee University and Tennessee State University, to promote Small Business Innovative Research (SBIR) grant opportunities. There were approximately 50 attendees from Tuskegee University and more than 30 from Tennessee State University attended. In both workshops, an overview of the SBIR process was provided, including information regarding the RFA, the required information (such as a DUNS number), the various topic areas available, describing a Cooperative Research and Development Agreement (CRADA), and Technical and Business Assistance (TABA) funding. Question-and-answer sessions followed each virtual workshop. Attendees included both campus-based employees and alumni who were entrepreneurs interested in academic and industry collaborations through enhancing technology transfer.

In FY 2021, several of NIFA's SBIR staff attended virtual SBIR conferences and delivered formal presentations on the program. Additionally, program staff conducted one-on-one virtual meetings with more than 100 entrepreneurs and discussed both SBIR opportunities and technology transfer opportunities. Staff members provided a USDA SBIR general overview to the Southern California Regional SBIR/STTR Conference, the New Mexico State University Ag Spring Accelerator, Utah Innovation Center, University of Illinois at Urbana-Champaign FAST, University of Arizona Tech Launch program, Washburn BRITE-SBDC, Greater Spokane PTAC, Tennessee State University, Tuskegee University, Nebraska Small Business Development Center (SBDC), Montana Innovation Partnership TechLink, Indiana SBDC, Arkansas SBDC, and the BBCetc SBIR Training with Federal Officers focused on underserved and rural regions. In addition, the SBIR staff presented an SBIR General Overview to NIFA's Quarterly meeting with 1890 Institutions.

Over the course of FY 2021, the USDA SBIR program, in conjunction with the Small Business Administration, had staff participate in two virtual SBIR Regional Road Tours, Midwest Road Tour and

South Road Tour, as well as National SBIR Week conferences. The focus of these tours and regional conferences was 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 1,000 attendees in total, provided 16 to 43 one-on-one meetings with small business entrepreneurs at each event, and covered the following States: Indiana, Nebraska, Missouri, Illinois, Mississippi, Texas, Oklahoma, Arkansas and Louisiana. The 2021 National SBIR Week provided outreach to over 5,700 attendees in total.

10.0 The Natural Resources Conservation Service (NRCS) Combined Metric Tables

Table 1: Other performance measures deemed important by the NRCS.

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Soils Research and Technology Transfer					
Number of publications by scientific or technology transfer staff			25	37	20
Number of talks, conference attendances, speeches, webinars (i.e., other forms of outreach) on Federal technology transfer		55	74	161	219
Number of new alliances, (e.g., partnership intermediary agreements, memorandums of understanding)	3	4	3	11	25
Plant Materials Centers (PMC)					
Number of technical publications	122	134	86	183	88
Number of talks and presentations to transfer plant materials information	86	68	72	47	46
Number of participants (internal and external) attending plant materials technology training sessions	2,467	1,515	3,187	1,086	2,559
Number of tours & field days	38	46	31	10	14

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Number of new conservation plant releases from PMCs	3	1	2	6	2
Conservation Practice Standards					
Development or revision of conservation practice standards	7	21	9	58	28
Conservation Engineering					
Number of talks, conference attendances, speeches, webinars (i.e., other forms of outreach) on Federal technology transfer				2	12
Number of new alliances, (e.g., partnership intermediary agreements, memorandums of understanding)				1	0
National Technology Support Centers					
Number of publications by scientific or technology transfer staff				2	21
Number of talks, conference attendances, speeches, webinars (i.e., other forms of outreach) on Federal technology transfer				2	53
Science and Technology Training Library					
Number of new webinars hosted				35	35
Number of participants who viewed webinars and training in the Training Library				9,884	35,019
Number of continuing education units				2,176	9,617
Soil Health					
Number of publications by scientific or technology transfer staff				117	97
Number of talks, conference attendances, speeches, webinars (i.e., other forms of outreach) on Federal technology transfer				204	91
Number of participants who viewed webinars				5,203	6,457
Number of demonstrations & field days				184	41

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Snow Survey and Water Supply Forecasting					
Number of publications by scientific or technology transfer staff	4	3	5	4	6
Number of talks, conference attendances, speeches, webinars (i.e., other forms of outreach) on Federal technology transfer	8	9	7	9	9
Number of new alliances, (e.g., partnership intermediary agreements, memorandums of understanding)	21	25	22	20	20
Number of demonstrations & field days	50	52	53	40	40
Soil Climate Analysis Network (SCAN) and Tribal SCAN installations	0	12	12	1	2
SNOTEL and Snolite installations	6	18	8	8	9
Snow surveys	1,588	1,572	1,579	857	857
Number of forecast points	600	600	600	600	600
Conservation Effects Assessment Project (CEAP)					
Number of publications by scientific or technology transfer staff					43
Number of talks, conference attendances, speeches, webinars (i.e., other forms of outreach) on Federal technology transfer					55
Number of new alliances, (e.g., partnership intermediary agreements, memorandums of understanding)					6
Number of contracts awarded to non-Federal entities for technology demonstration and transfer					7
Number of participants who viewed webinars					1,937
Number of demonstrations & fields days					2
Conservation Innovation Grants (CIG)					

	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
CIGs awarded to non-Federal entities for technology demonstration and transfer	110	81	96	90	77[1]

10.0. Natural Resources Conservation Service (NRCS)

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 Nation's premier agency for transfer of applied natural resources conservation approaches and technology. NRCS maintains 170 National Conservation Practice Standards. These standards and supporting documents are NRCS's primary vehicle for transferring the latest science and technology directly to America's farmers and ranchers to ensure the long-term sustainability of American agriculture.

10.2. Nature and Structure of Technology 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 conducts conservation field trials and on-farm trials to strengthen NRCS technology delivery and to 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. NRCS also assesses the efficacy of its conservation practices and activities and incorporates new methods or technology into its practices. NRCS scientists and specialists across many organizational units are involved in developing or evaluating new technology, adapting technology into a usable format for NRCS activities, and incorporating technology into NRCS conservation practices and tools that are used by field staff, conservation partners, and customers to conserve our Nation's natural resources. The sections below provide details on the divisions and programs that contribute to NRCS technology development and transfer efforts.

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.

**Predicting Valley Fever Habitat Using Soil Survey Data**

Valley fever is a disease caused by fungi that live in arid soils, mainly found in the Southwestern United States, however, recent infections suggest a wider range. The disease often presents medically like an upper respiratory infection and is sometimes treated ineffectually with antibiotics. By being able to trace a patient's travels to a locality where *Coccidioides* may occur, proper treatment (antifungals) can be prescribed. Despite a growing body of scientific evidence describing the soil conditions where the fungi might be found, maps of the distribution of the fungi remained very general. Since research suggested that soil and climatic properties constrain the possible habitat for the fungi, SPSD was able to test a

hypothesis that a viable interpretive model could be developed for predicting the distribution of the fungi that cause Valley fever using data available in the soil survey database. Collaboration with staff of the Centers for Disease Control and Prevention Mycotic Diseases Branch eventually led to the publication of "Using soil survey data to model potential *Coccidioides* soil habitat and inform Valley fever epidemiology" in the journal PloS ONE (https://doi.org/10.1371/journal.pone.0247263). While SPSD does not know if any physicians have used the data to help decide on the diagnosis for a patient, SPSD does know that the online publication has been viewed 743 times and downloaded 230 times since February 19, 2021. The supporting data has been viewed 91 times and exported 157 times. The broader implications are that the SPSD can offer assistance to new collaborators and the usefulness of soil survey data and interpretations has been demonstrated in a meaningful way.

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/.

In 2021, as the focus shifted to field work to complete the Provisional Ecological Site Initiative (see figure), the National Ecological Site team (NEST) emphasized development of new applications for information and new tools for analysis.
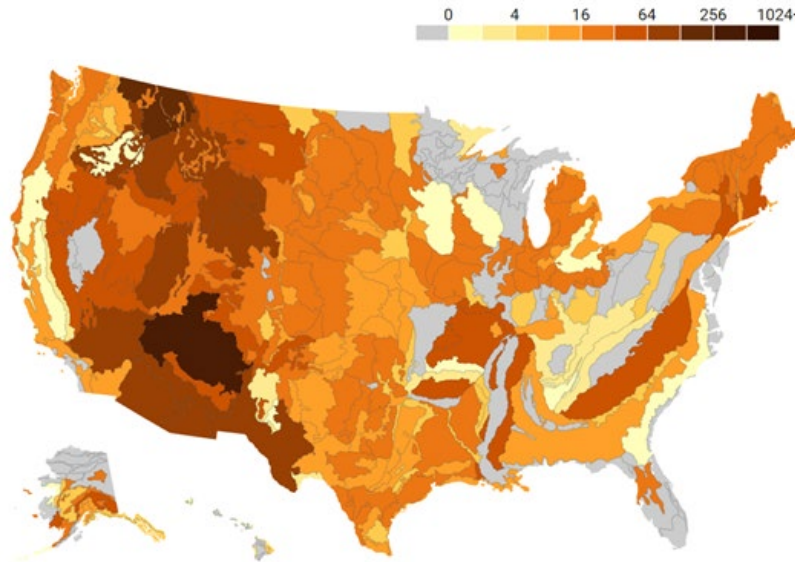
Number of publicly available ecological site descriptions (11/15/2021).

In 2021, the NEST developed a host of new tools to help developers and users assess and manage the quality of information in ESDs. SPSD developed five new web services reports that field, regional, and national staff can use to assess the completeness and consistency of information. These reports allow the user to determine if individual ESDs within a major land resource area (MLRA) have complete quantitative characterization of the geographic extent, physiography, climate, and soils. These complete and consistent characterizations are necessary for identifying information gaps and for populating predictive models of responses to management actions and climate change across landscapes and regions. These reports (and maps) can be found at https://edit.jornada.nmsu.edu/catalogs/esd/reports.

ESDs not only contain information valuable to model developers to predict the impacts of changes in management and climate on soil/vegetation relationships, the State-and-Transition Models (STMs), they also provide a framework for connecting model results to on-the-ground decision making. In 2021,

SPSD collaborated with several groups to develop new approaches to populate site-specific STMs with information relevant to conservation decision making:

- Collaborated with IBM to organize the existing Pedon data, National Soil Information System and EDIT datasets, along with available climate datasets, and create metrics for assessing the variability within MLRAs and ESs delineations. These refined groupings should reduce the variability in the response to management actions and improve the predictions of changes in ecosystem services.

- Developed new tools for incorporating the outputs of wind and water erosion models into STMs.

- Collaborated with the U.S. Forest Service and ARS to develop a new approach to using ST-Sim, a simulation model that can incorporate climate change into STM development.

- Collaborated with ARS and university faculty to develop new guidelines and equations using the Conservation Resources Land Management Operations Database tool to characterize operating systems that can be used to inform the development of STMs and predict their impact on erosion susceptibility and dynamic soil properties. These improvements are especially important as crop and pasture lands are incorporated into ESDs.

- Updated the Interpreting Indicators of Rangeland Health worksheet format for individual ESs in EDIT. These worksheets are integral to conservation planning and implementation of conservation programs on rangelands throughout the United States.

- Worked with U.S. Geological Survey and New Mexico State University to develop a protocol and pilot project to demonstrate how ES and STM information can be used to more credibly assess the impact of conservation practices using a synthetic control treatment approach.

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. A new version of PLANTS was released to the public in April 2021. This release is the first step in a modernization effort that will also include a content manager and a Web Services API. These development efforts will allow PLANTS data to be rapidly updated and PLANTS users to readily download large data sets.

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, 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 2021, the KSSL conducted analysis and validation on 8,111 soil samples collected from individual soil horizons that represent 1,808 soil profiles (pedons). The soil samples analyzed in 2021 come from NRCS and other agency customers that include soil survey field offices, State soil scientists, resource soil scientists, university cooperators, nongovernmental organizations, Plant Materials Centers, Natural Resource Inventory (NRI) Soil Monitoring Network, the National Ecological Observatory Network, National Wetland Condition Assessment, and outreach activities such as collegiate soil judging and the United Nations-Food and Agriculture Organization (UN–FAO). During 2021, the KSSL recorded 118,250 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 Technical Assistance and Farm Bill programs. 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 assessment programs and provides technical consultation and reference samples to other soil laboratories, while participating in laboratory proficiency testing programs. The quantitative soil data produced by the KSSL serve as inputs for soil survey, models, and interpretations, decisions around best land use and management, and soil health assessment and monitoring; measured values also help determine effectiveness of conservation practices and programs (e.g., Conservation

Effects Assessment Project, Environmental Policy Integrated Climate model, and Revised Universal Soil Loss Equation).

The NCSS Characterization Database is maintained and delivered by the KSSL. It delivers a comprehensive soil laboratory dataset of chemical, physical, and mineralogical properties from over 64,000 sample sites, which are the result of 120 years of inventorying soils of the United States and territories. The database is used by a wide range of customers, including farmers, ranchers, internal USDA staff, other Federal agencies, nonprofit organizations, local governments, and university partners.

The KSSL participates in the Food and Agriculture Organization (FAO), Global Soil Partnership (GSP), Global Soil Laboratory Network (GLOSOLAN) (http://www.fao.org/global-soil-partnership/glosolan/en/), that facilitates harmonization of methods of analysis and standards for laboratory quality control, and improve capacities of laboratories worldwide to perform soil analysis. The 4th Annual GLOSOLAN meeting was held Nov 11–13, 2020 (http://www.fao.org/global-soil-partnership/resources/events/detail/en/c/1305637/ and was attended by a cross-section of NRCS–SPSD employees; KSSL presented (http://www.fao.org/global-soil-partnership/glosolan/presentations-4th-glosolan-meeting/en/). The meeting reviewed accomplishments and established plans for 2020–2021. Since then, the KSSL has actively participated in global exercises to GLOSOLAN Standard Operating Procedures (SOPs) for:

- soil pH determination: http://www.fao.org/3/cb3637en/cb3637en.pdf

- soil electrical conductivity (soil/water, 1:5): http://www.fao.org/3/cb3354en/cb3354en.pdf

- saturated soil paste extract: http://www.fao.org/3/cb3355en/cb3355en.pdf

- soil available P - Bray I and Bray II methods: http://www.fao.org/3/cb3460en/cb3460en.pdf

- soil available P - Olsen method: http://www.fao.org/3/cb3644en/cb3644en.pdf

Over the last 11 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 already represents almost 90,000 legacy samples from the KSSL soil archive, the largest public collection in the United States with over 400,000 specimens. Geographically and taxonomically diverse calibration models are being developed for use by NRCS soil survey field offices for rapid prediction of soil properties such as soil organic carbon from MIR spectra, with attractively low errors. MIR spectrometry allows rapid data collection while assuring data quality and consistency using 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 and spectral data and its open data policy, the KSSL holds a coleadership role in the GLOSOLAN soil infrared spectrometry initiative (http://www.fao.org/global-soil-partnership/glosolan/soil-analysis/dry-chemistry-spectroscopy/en/). Infrared spectrometry allows rapid and reliable estimation of soil properties pertaining to soil classification and soil health assessment. From this coleadership role, the KSSL was selected to develop a global spectral calibration library which would contribute to capacity building in soil spectrometry and soil property estimation worldwide. In FY 2021, the KSSL completed draft SOPs for sample preparation and MIR spectral data collection, that will also help regional champion laboratories support capacity building activities in soil spectrometry.

NRCS Investments in University Research

The SPSD has invested $2.3 million in 10 collaborative research agreements with 10 universities in 2021 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 2021 included development of soil health measurement techniques, assessing soil carbon sequestration by revisiting legacy data collection sites, expanding soil property information and interpretations to include wildfire susceptibility and risks, and evaluating data and tools for short-term decision making related to floods, landslides, and ecosystem recovery after forest fires.

New Guide Cooperatively Developed to Assist Landowners With Salinization of Working Lands in the U.S. Southeast

A new guide—*Identification, Mitigation, and Adaptation to Salinization on Working Lands in the U.S. Southeast*—was developed cooperatively between USDA Southeast Climate Hub staff (Forest Service) and NRCS Climate Hub Liaisons with partial funding from the NRCS Soil Science and Resource Assessment Deputy Area. The guide is designed to assist Southeastern landowners and support professionals (cooperative extension agents, NRCS field and conservation district staff, and private consultants) in determining the affected agricultural land's stage of soil salinization. Guidance includes assessing soil salinity conditions, recommendations for mitigating soil salinization based on the cause and salinization stage, and expected production reductions for economically important crop species and

cultivars across various soil salinity levels. The salinization levels have been divided into stages to allow the producer to assess the soil's condition and management options more easily. These stages help determine when farming or forestry is no longer advisable and when the land could be better used as a conservation easement. The appendix includes lists of useful links and resources containing information on the topics covered in this guide. The recommendations and information in the guide provide landowners with a base of information to discuss further with county extension specialists, soil conservation district/NRCS field staff, other professional technical service providers, or agricultural consultants.

Conservation Assessment Ranking Tool

NRCS leadership recognizes the foundational role soils information is for the agency to continue to efficiently and effectively provide technical assistance and support to landowners. The increasing availability of geospatially referenced natural resource data (e.g., soil, climate, land cover) and the expansion of computing resources and web feature services does allow the opportunity to provide field staff with an unprecedented amount of information to help support and inform their discussions with landowners. The 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 assessment and application process. The tool combines and analyzes geospatially referenced data and site-specific information provided by the landowner within a decision support system framework.

 Soil's information is used in the assessment part of CART; documentation for soils data inputs into CART are at https://jneme910.github.io/CART/.

Month	# Soil Resource Concerns Assessed in FY 2021
2020 - October	581,996
2020 - November	957,235
2020 - December	1,083,081
2021 - January	763,211
2021 - February	935,611
2021 - March	1,148,539
2021 - April	1,004,057
2021- May	1,094,457
2021- June	1,122,317
2021- July	910,628
2021 - August	805,880
2021 - September	604,955

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. PMCs have applied research authority to evaluate plant materials and plant materials technology for solving natural resource problems and improving the utilization of natural resources. Each PMC addresses the high-priority conservation concerns within unique ecological areas. When appropriate, PMCs 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.
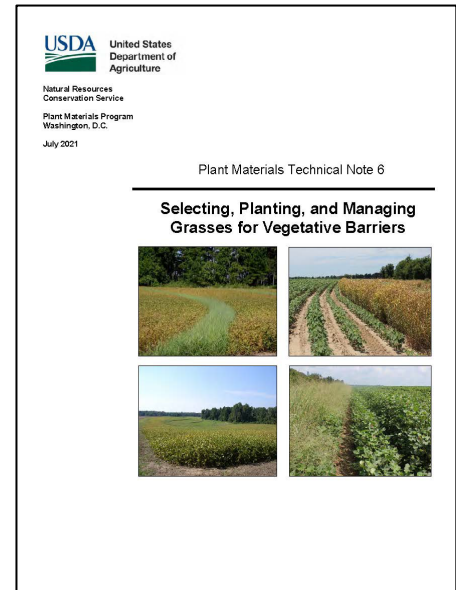
- Evaluating new plant materials and releasing promising materials to the public for the commercial production of plant materials to protect and conserve natural resources.

- 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 11 new study reports, the application of PMC vegetative information in 16 new technical notes or conservation practice implementation requirements, and information on the use, establishment, and management of conservation plants in 10 new or revised plant guides. Two national technical notes—Using the Appropriate Legume Inoculant for Conservation Plantings and Selecting, Planting, and Managing Grasses for Vegetative Barriers—and two regional technical notes—Selection and Use of Native Warm-Season Grass Varieties for the Mid-Atlantic Region and Giant Cane and Other Native Bamboos: Establishment and Use for Conservation of Natural Resources in the Southeast—were released in 2021. These technical notes, and many other PMC State technical notes and publications, provide vegetative information packaged for NRCS conservation planners and customers to assist with implementing conservation practices.

This new NRCS national technical note provides information to landowners on stiff, dense grasses that meet the standards of the Vegetative Barriers conservation practice, which is a low-cost and effective way to reduce sheet and rill erosion, decrease ephemeral gully erosion, manage water flow, stabilize steep slopes, and trap sediment in cropland fields.

- The Plant Materials Program website consists of over 3,000 technical documents downloaded more than 1.5 million times per year. Plant Materials Program studies resulted in the addition of 88 new technical documents to the website in 2021.

- Plant Materials Program staff conducted 53 technical training sessions for 2,100 participants

in 2021. Training topics included selecting, planting, and managing cover crops; selecting

and establishing conservation plants; plant identification; planning a conservation planting;

enhancing wildlife and pollinator habitat; improving the productivity of range and

pastureland; planting windbreaks and hedgerows; and importance of vegetative covers for

preventing erosion. 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 3,000 participants including

NRCS employees, Federal and State government employees, farmers, ranchers, and the

general public. PMC trainings, field days, and tours continue to be impacted in 2021 by

COVID-19 restrictions, though many PMCs have been able to reach their customers through

virtual events

- 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 Plant

PMCs have released 753 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 580 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 2021, PMCs released two new conservation plants to the public and commercial growers:

- [Centex Germplasm threeflower melicgrass](#) (*Melica nitens*) was released by the Knox City, Texas PMC. Centex Germplasm is a native cool-season perennial bunchgrass recommended for critical areas, wildlife habitat plantings, and to add diversity in range and pasture plantings in central and west Texas.

Centex Germplasm threeflower melicgrass

- [Permian Germplasm whiplash pappusgrass](#) (*Pappophorum vaginatum*) was released by the Knox City, Texas PMC in cooperation with the Texas Natives Seeds program of Texas A&M University-Kingsville. Permian Germplasm is a warm-season perennial bunchgrass recommended for critical site revegetation, roadside plantings, rights-of-way plantings, erosion control, upland wildlife habitat, and rangeland plantings in central and west Texas.

10.5 Conservation Practice Standards

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) are developed to ensure the conservation practices are 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 initiates the review or development of a CPS and the associated documentation. The standard is reviewed or developed in a multistep process starting with creation of an interdisciplinary review (or development) team to review/develop the CPS. Members of the team are 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 2021, 28 CPSs were revised.

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 technical releases (TR). Engineering national discipline

leads 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. In FY 2021, NRCS archived 36 percent of the obsolete directives. The removed, obsolete directives will be available on the engineering technical directives archive webpage.

CED continuously updates the NEH series to provide NRCS staff and stakeholders with current approaches and technologies for engineering solutions. In FY 2021, CED issued the second edition of the National Engineering Field Handbook, Part 650. This handbook is the primary reference utilized by NRCS field staff for planning, designing, and implementing simple engineering conservation practices.

Collaboration with the American Society of Civil Engineers

NRCS collaborates with the American Society of Civil Engineers' (ASCE) 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 760 individual training webinars and 30 guided online courses. The ASCE catalog includes over 1,000 individual, group, live, or on-demand webinars and 12 6-week courses. This effort enables NRCS engineering staff to provide our stakeholders with high quality engineering solutions based on current approaches and technology. The current contract has been renewed through September 30, 2023.

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:

- Performed geotechnical analysis, soil mechanics testing, and prepared full reports for the repair and rehabilitation of 10 dams with notable dam safety concerns. The laboratories performed two preliminary sites for analysis of the auxiliary spillways and supplicant overall plan on the rehabilitation of the dam.

- Performed geotechnical design analysis, geotechnical testing, and prepared full reports for 9 smaller EQIP and C0-01 structures (under 40-ft. high embankment), and 84 CO-01 and EQIP work with lagoons and waste storage structures. These types of structures play an important role in our agency's emphasis on water quality.

- Performed geotechnical analysis and soil mechanics testing for 3 channel stabilization projects and 17 other miscellanies projects related to Wetland Reserve Program, Wildlife Habitat Incentives Program, and EQIP not related to agricultural waste.

- Performed rock testing and prepared reports for two quarry sites relating to determining material specifications adequacy and quarry use approvals.

- Performed field investigations and assisted as committee members in the preparation of two engineering reports to aid in determining dam safety concerns as well as obtaining rehabilitation or remedial repair funding.

- Performed 102 Atterberg limits tests for the NSSC.

National Design, Construction, and Soil Mechanics Center–Design and Construction

The National Design, Construction, and Soil Mechanics Center (NDCSMC) 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 EQIP and rehabilitation of aging watershed structures. A few examples include:

- Completed over 50 reviews on complex class VII and VIII engineering structures such as dams, wetlands, stream restoration, and large irrigation projects.

- Delivered, in cooperation with NRCS State and NRCS center personnel, a variety of virtual training classes including topics such as Civil 3D Surfaces and Gradings, Hydrologic Engineering Center River Analysis System Software for NRCS, and Stream Restoration and

- Stream Stabilization. Many of these classes were formally taught in person but have been modified for virtual delivery. One of the advantages of remote instruction is being able to include a larger and more diverse training cadre.

- Presented virtual talks for the east, central, and west dam consortiums on topics ranging from internal erosion to sedimentation.

  Provided direct assistance to States on various topics including stilling basin structural design, pole building design, chimney filters, livestock watering, aquatic organism passage planning, and developing a scope of work for dam rehabilitation. Many of these direct assistance efforts were formally done in person but remote work has required use of virtual tools.

- Presented, in cooperation with the national geologist, West National Technology Support Center, and The Nature Conservancy, a webinar titled "Geology, Hydrology, and Biology of Springs." This webinar addressed the ecological functions of springs and implications for planning spring developments from an NRCS perspective.

- In cooperation with other NRCS center staff, provided technical support for a variety of efforts including the Climate-smart ag practices and technologies for the Foreign Agricultural Service, Chesapeake Bay Program Technical Workgroup on Non-Urban Restoration, and the "Expert-to-expert virtual meeting on Soil Health to inform UN Food Systems Summit." NDCSMC personnel also participated in the virtual-based close-out meeting of the International Center for Agricultural Research in the Dry Areas – USDA Program Role of

ASPs for Technology Transfer to the Farmers which closes out approximately a decade of work engaged by NDCSMC personnel in Pakistan.

- Represented NRCS on committees responsible for establishing industry engineering standards, such as the ASTM International, 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 Island and Caribbean Areas, and

- To acquire, develop, and support science and technology that efficiently meets the needs of the NRCS conservation delivery system.

The NTSCs are a critical vehicle for technology transfer from NRCS technical specialists down to State and area offices. States submitted over 1,000 technical assistance requests to the Central NTSC, 1,354 to the East NTSC, and 424 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, the Conservation Practice Document-Document Management System (CPD-DMS),

planning/Field Office Technical Guide (FOTG), economics and social sciences, energy, air quality, 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 FOTG more efficient at the national and State levels. Those applications are the CPD-DMS, Conservation Practice Data Entry System (CPDES), and FOTG. The 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.

- 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, technology, and software include:

  o Continued updates to the successful rollout of the Stewardship Tool for Environmental Performance (STEP) process in CART. In FY 2021, the NWQQT developed variable credits for multiple practice narratives that focus on specific resource concerns.

o 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.

o Substantial progress was made on the development of an edge-of-field (EoF) water quality monitoring reporting and document management system. In FY 2021, 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.

o Continuing support for Field to Market's (FTM) 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.

o   Continued the development and maintenance of nutrient management and pest management technology tools based on site risk. 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's work with USDA partners, conservation districts, land grant universities, TSPs, industry, and nongovernmental conservation partners continues to be critical for improved nutrient and pest management.

o   Continued to support software development/legacy software enhancement with the NRCS Information Technology Center in Fort Collins, CO, and Kansas State University on hydrology and hydraulic tools (Engineering Field Handbook "Chapter 2", WinTR-55 computer program, WinPond, and WinTR-20 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 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, 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. Activities include—

- o Webinar for Washington State University on CNMP planning tools such as NMTracker and GNT mapping tool.

- o Presented the topic "Manure Application Impact to Nutrient Runoff" at the American Society of Agronomy International Meeting.

- 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 2021, the team continued assisting several States with their NRCS National Air Quality Initiative (NAQI) efforts. The NAQI is a separate set of funds carved out from the Environmental Quality Incentives Program that are available to States to specifically target air quality issues.

  - o In FY 2021, NAQI funds were requested and received by the Arizona, California, Colorado, Maryland, Texas, and Washington NRCS offices. NAQACT worked extensively in FY 2021 with the Maryland and Colorado NRCS offices to refine their approaches to the NAQI and identify opportunities for better targeting NAQI funds in those States. In the past, funds have been used to replace high-emitting diesel engines in California, apply poultry litter amendments at poultry farms in Maryland and Delaware, replace smudge pots for frost protection in Oregon, establish buffers in Pennsylvania, reduce ammonia emissions along Colorado's Front Range, and reduce windblown dust from wind erosion in Texas and Oklahoma.

  - o Dedicated time in FY 2021 to add several new national payment scenarios for Conservation Practice Standard (CPS) 371 – Air Filtration and Scrubbing. These

technologies offer ways to improve air quality and reduce hazards to human and animal health from barns and other enclosed structures. They have been used for many purposes, from reducing ammonia emissions in poultry houses to reducing dust from grain handling operations. In addition to the existing scenarios for biofilters, new scenarios for fan exhaust windbreak walls, wet scrubbers, outdoor electrostatic precipitators, in-barn electrostatic precipitators, fabric filters, cyclones, carbon adsorbers, and biotrickling filters are now available for States to adopt. A new national payment scenario for increasing pen stocking density to add moisture for reducing dust emissions was also added to CPS 375 – Dust Management for Pen Surfaces.

- 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 2021, the National Grazing Lands Team:

  o Developed and published the National Range and Pasture Manual. The manual describes the policy for providing technical assistance on grazing lands including pastureland, rangeland, grazed forestland, hayland, and grazed cropland.

  o Updated/Revised 11 chapters of the NRCS National Range and Pasture Handbook; the remaining three chapters will be completed in 2022. The handbook is a companion document to the new manual. Chapters provide technical information related to the current extent of grazing land resources, ecological sites, resource concerns and rangeland trends and conditions, rangeland ecohydrology, rangeland soil health, livestock nutrition, wildlife planning considerations, grazing economics, inventory, assessment and

monitoring of grazing lands, and pollinator considerations for range and pasturelands.

o Developed the Rangeland Hydrology and Soil Erosion Processes Handbook and the
Rangeland Hydrology Erosion Model Guide jointly with ARS. The handbooks teach
NRCS employees the causes and consequences of soil erosion on rangelands and how to
design management plans to prevent or correct issues of concern on rangelands at scales
ranging from hillslopes to watershed.

o Team members serve as subject matter experts, instructors or technical coordinators for
the following Employee Development Section courses: Range Ecology I, Range Ecology
II, Rangeland Ecohydrology, Interpreting Indicators of Rangeland Health, Vegetation
Monitoring and Data Interpretation, Grazing Land Economics, and Prescribed Grazing.

o Provided Rangeland Hydrology Erosion Model updates to the ARS Great Basin
Rangelands Research Unit in Reno, Nevada.

o Analyzed NRI data regarding milkweed and monarch butterfly and submitted paper to
Ecosphere.

o Prepared and distributed range and pastureland NRI data to States for (1) developing
strategic plans for conservation programs and applications of State resources, (2)
developing rangeland ecological sites, and (3) reporting current trends and conditions.

o Assisted the Great Plains Biome Initiative, providing NRI data on shrub encroachment,
milkweed distribution and extent in the Great Plains (which is helping States to prioritize

conservation efforts on rangeland technical assistance), brush management, and pollinating insects.

- 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 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 ondemand. In FY 2021, these NRCS-sponsored webinars in the Training Library were viewed by over 34,256 individuals, including both NRCS and non-NRCS participants. Webinars were viewed live by 7,671 participants, and 26,585 participants viewed the webinars in the ondemand format. More than 10,984 continuing education units were issued to maintain professional certification for NRCS employees, partners, and other participants. Of these, 1,367 were certified crop adviser credits and 9,617 were conservation planner credits. A total of 17,450 certificates were earned from the NRCS-sponsored webinars.

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. Nearly a decade ago NRCS launched its Soil Health Initiative to refocus agency efforts on improving the physical, chemical, and biological functioning of soil on private lands and, shortly after that, established the national Soil Health Division (SHD). The SHD provides leadership training on soil health and technical assistance with internal and external 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 2021.

The SHD recently developed a soil health strategy template for each State to use in development of their own State strategy. It compiled successful strategies and approaches from States across the Nation which have built successful soil health efforts over the past years. All States are now 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.

Each year the SHD performs soil health-related outreach and technology transfer that reaches 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

2021, SHD staff provided training on a wide range of soil health assessment and management topics at nearly 200 events, including soil health trainings, presentations, and demonstrations to agency staff or mixed stakeholder and grower audiences.

To remedy the impact of reduced inperson staff trainings for conservation planner certification resulting from the pandemic, SHD modified all PowerPoint presentations for a virtual or live-streaming delivery, developed ondemand 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. The SHD conducted 36 of the virtual soil health certification courses to over 1,200 agency employees and partners. Additionally, one of the soil health certification courses was professionally recorded in a live/virtual mixture setting and is currently being developed into a training tool for planners.

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. Eight events were held in FY 2021, each attended by 300–500 participants, with over 10,000 total views since the start of the series. These conversations complement over 100 soil health-related webinars that are available to the public on demand at the NRCS Science and Technology Training Library. These webinars attracted nearly 5,000 attendees in FY 2021. NRCS's "Science of Soil Health" videos, available on YouTube, have been viewed over 645,000 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.

- Recorded a video demonstration for the NRCS In-Field Soil Health Assessment with Clemson University and the University of South Carolina as part of a USDA Sustainable Agriculture Research and Education project.

- Revised Technical Note 450-06, "Announcement of the Cropland In-Field Soil Health Assessment Guide." This guide can be used to assist in determining the presence of soil health-related resource concerns. This assessment supports aggregate instability and soil organism habitat degradation, which are two soil health resource concerns that were approved in FY 2020, as well as soil organic matter depletion and compaction, which are the previously existing soil health resource concerns.

- Soil Health Management Plan Conservation Planning Activity (CPA 116) and Soil Health Management Design and Implementation Activity (DIA 162) revised to fulfill the agency Conservation Activity Plan (CAP) Transition, providing technical and financial assistance for soil health management planning through current program delivery processes.

- Soil Health Testing Conservation Evaluation and Monitoring Activity (CEMA 216) developed to meet Farm Bill 2018 mandate for technical and financial assistance for soil health testing and fulfill the agency CAP Transition.

- 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 were released on NRCS agency's YouTube site in 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 SHD staff have been working with all councils to verify and deploy new decision support tools.

The third 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 decisions, as well as economic, environmental, and social outcomes. Six additional Soil Health Demonstration Trial projects were funded in FY 2021. These cooperative grants to organizations leading the trials in 15 States and U.S. territories total to nearly $9 million. The trials will develop a better understanding of and guidance for key implementation gaps, including, but not limited to increasing the resilience of dryland cropping systems, addressing barriers to soil health practice adoption by small-scale historically underserved producers, grazing innovations, water quality and quantity, and furthering soil health management system adoption.

Highlight Story: Soil Carbon Amendment

The SHD worked with California several years ago to develop an interim practice standard on compost and biochar application to soils. This concept was directly connected with several partner initiatives to

promote carbon farming and manage organic waste and surplus food in California. With increasing interest in climate mitigation and adaptation across the country, there is even more investment by State and Federal agencies to reduce methane emissions from landfills, sequester more carbon through the application of biochar, and reduce organic wastes.

The Soil Carbon Amendment interim practice (Code 808) supports the application of compost, biochar and other carbon amendments and includes whole orchard recycling, further illustrating and supporting the connections between soil health and climate mitigation, adaptation, and resilience. The interim was adopted by more than 20 States in FY 2021, and planned on more than 20,000 acres. NRCS began the review process for Interim CPS Soil Carbon Amendment (Code 808) to become a permanent practice standard under the same name and Code 336.

To provide the best technical assistance, SHD developed a factsheet and a frequently asked questions document to provide guidance to planners across land-use applications. On May 27, 2021, the SHD presented and recorded the 15th installment of "Conversations on Soil Health" series, focused on biochar with expert speakers from across USDA and academia.
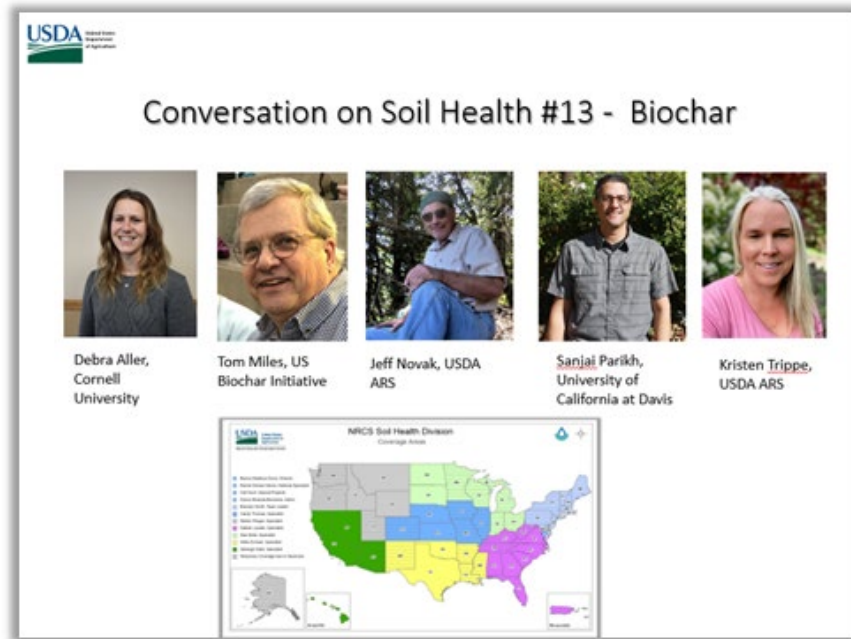
10.10. Watershed Protection and Dam Safety

The Emergency Watershed Protection Program (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 2021, 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 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 with universities, researchers, and other strategic partners advancing snow measurements and hydrologic forecasting. SSWSF collects high-elevation snow and climatic data and produces water supply availability forecasts. Data are stored in Water and Climate Information Systems' (WCIS) databases and provided to an extended array of stakeholders through online presence and outreach. NWCC also supports the Soil Climate Analysis Network across the country further contributing soils and moisture data. SSWSF has a collaborative agreement with the U.S. Bureau of Reclamation to investigate increased on-the-ground snow parameter collection in support of snow

modeling and to pursue research using airborne data to advance water supply forecasting. NWCC has a partnership with National Aeronautical and Space Administration's Jet Propulsion Laboratory's Western Water Assessment Office to evaluate remotely sensed data for both snow data quality control and to improve forecasts. NWCC is advancing infrastructure to support forecast modeling using the Multi-Model Machine Learning Metasystem 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. Finally, the NWCC's interactive map (https://www.nrcs.usda.gov/wps/portal/wcc/home/quicklinks/imap) is an extensively used tool providing both current and historical information on water and climate related data. The map interface provides indepth user-friendly WCIS data evaluation. Allowing presentation of data from multiple sources in the interactive map is a form of collaboration reducing a user's need to navigate various locations.

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 Effects Assessment Project

The Conservation Effects Assessment Project (CEAP) is a multi-agency effort designed to quantify the effects of conservation practices on agricultural land and to provide a scientific basis for managing the agricultural landscape for environmental quality. To build the science base necessary for effective conservation planning, CEAP collaborates with a number of partners from across the spectrum of the conservation research and planning community, including academic partners, nongovernmental organizations, and government collaborators at the local, State, and Federal levels. While findings from assessments completed under CEAP are used internally to guide USDA conservation policy and program development, CEAP partners and the CEAP team also engage in various knowledge transfer activities to make tools, data, analytical products, and findings developed through CEAP available externally to researchers, conservationists, producers, and other external groups to amplify their usefulness and more broadly advance the science of conservation planning and decision making.

Technology transfer activities are tailored to specific audiences and include journal articles, technical publications, conferences, and training for the research and conservation communities as well as webinars, field days, videos, and blogs for less technical interested audiences. In FY 2021, CEAP component leaders and CEAP partners prepared 43 technical publications and participated in 44 talks and conferences, while also presenting 11 webinars on outcomes-related findings, data, and tools that reached approximately 1,900 participants.

10.14. Conservation Innovation Grants

Another important vehicle for development of conservation technology that NRCS will then transfer to farmers and ranchers is Conservation Innovation Grants (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. In 2019, CIG added an On-Farm Trials (OFT) component. CIG OFT grant recipients offer incentive payments to compensate agricultural producers for adopting and evaluating new conservation approaches.

Both CIG award types enable 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 800 national-level CIG Classic and OFT grants. In FY 2021, 19 national-level CIG Classic and 18 national-level CIG OFT 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. In FY 2021, 50 State-level grants were awarded; States have made over 900 awards since 2004. Lists and brief summaries of funded projects are available on the CIG website: https://cig.sc.egov.usda.gov/.

11. 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 $50 billion in 2021 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 such 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 underserved 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 underserved 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.