



Forest Service  
U.S. DEPARTMENT OF AGRICULTURE

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# USDA FOREST SERVICE FY 2020

## ANNUAL REPORT ON TECHNOLOGY TRANSFER



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## 6.0. Forest Service

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

<https://www.fs.usda.gov/>

## 6.1. Understanding

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

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

## 6.2. Mission Statement

The overall mission of the Forest Service (FS) is to “sustain the health, diversity, and productivity of the nation’s forests and grasslands to meet the needs of present and future generations.” Established in 1905, the FS is an agency of the U.S. Department of Agriculture (USDA) that directly manages 193 million acres of public land in national forests and grasslands and works with state forestry agencies and other partners to assist in managing 491 million acres of state and private forest lands. **The FS is the only land management agency in USDA.** Gifford Pinchot, the first Chief of the Forest Service, summed up the mission of the Forest Service “to provide the greatest amount of good for the greatest amount of people in the long run.” The Forest Service is composed of five areas: National Forest System (NFS), Research and Development (R&D), State and Private Forestry (S&PF), Business Operations, and Work Environment and Performance.

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

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

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

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

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

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

## 6.3. Nature and Structure of Research Program

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

### Research Priority Areas

- Applied science to support shared stewardship and improve forest conditions (e.g., market analyses, scenario planning, large landscape research, and decision support to further forest planning)
- Forest inventory and trend analysis (e.g., Forest Inventory and Analysis program, Resources Planning Act assessment, iTree forestry tools, National Woodland Owner Survey)
- Enhancements to the wildland fire system, including prediction, planning, decision support, impact assessment, and recovery
- Wood product and market innovations

### Research Framework

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

### Foundational Research Areas

- Forest and grassland health
- Forest soils, air quality, and hydrology
- Silviculture and ecology (including forest ecology and fish and wildlife ecology)

Today, research is conducted by more than 400 scientists and several hundred technical and support staff located at 67 sites across the United States. This structure provides sites for long-term science and management studies of major vegetation types found across the United States, as well as diverse research areas operated in collaboration with partners. The FS R&D organization includes five research stations (Northern, Pacific Northwest, Pacific Southwest, Rocky Mountain, and Southern); the Forest Products Laboratory; the International Institute of Tropical Forestry in Puerto Rico; and R&D Headquarters in Washington, DC. Although not in the research deputy area, there are also two Technology and Development Centers operated by the National Forest System located in Missoula, Montana and San Dimas, California.





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

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

While National Program Leaders (NPLs) do not have budgetary or supervisory authority over Station programs and scientists, they coordinate national and Station elements of their research areas and, ideally, work with other NPLs and Station leadership and scientists to develop Station research priorities and programs that effectively address national issues as well as local and regional ones. In some cases, NPLs make recommendations regarding the use of WO funds to coordinate research inputs among Station Scientists and to support grant programs in accordance with specific WO projects of national scope.

### R&D Foundational Assets

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

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

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

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

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

The principal contact for technology transfer via intellectual property agreements, patents, and licensing within the Forest Service is the Technology Transfer Coordinator (TTC), who reports to the Washington Office (WO) and is located at the Washington Office and Baltimore field office. The Forest Service Patent Program receives and tracks all invention disclosures, providing guidance to scientists regarding all aspects of intellectual property protection. The Forest Service Patent Program is changing the emphasis from utility patent filing to provisional application filing and seeking a development partner and/or extensive marketing prior to a decision to file the utility patent. Reducing the technology to practice under a cooperative research and development agreement (CRADA) greatly increases the opportunity for successful development. The goal of this program is to file provisional patent applications and involve the inventing scientist to help find a CRADA partner prior to filing a utility patent. This process includes working with the USDA Small Business Innovation Research (SBIR) program. The Patent Program conducts prior art searches and prepares all needed paperwork for the U.S. Patent and Trademark Office. The Patent Program also oversees contract law firms that draft utility patent applications (applications are filed by USDA Office of General Counsel), and files and prosecutes applications in the Patent Office. Draft patent licenses are prepared by the Forest Service Patent Program and signed by the Agriculture Research Service Office of Technology Transfer. Forest Service commercial licenses are royalty-based only with a priority toward making the technology available for internal Forest Service management use along with industry support.

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

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

R&D will also continue to build a scientific foundation for natural resource management and policymaking at multiple spatial scales in forest and rangeland ecosystems. Methods used include conducting leading-edge research, synthesizing existing research, and improving access to and highlighting field research to identify and prioritize critical management-driven needs. The data and research generated through this work are an important part of US Forest Service technology transfer, and US 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, USFS 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. US Forest Service will also continue to add data collection points to its internal data collections programs, Research Information Tracking System (RITS) and iWEB, to allow better reporting, distribution, and management decisions.

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

## 6.6. Forest Products Laboratory

The Forest Products Laboratory, based in Madison, Wisconsin, promotes healthy forests and forest-based economies through the efficient, sustainable use of our wood resources. The long-term health of our Nation's forests depends on sound conservation practices, including utilization. Since 1910, the Forest Products Laboratory (FPL) has used science and technology to conserve and extend our Nation's forest resources. Many everyday products and processes have been improved through FPL research, such as building products (structural and composite), housing, paper, bridges, adhesives, packaging, recycling, biofuels, and wood preservatives, to name a few. Historically, FPL has contributed to great improvements in areas such as wood finishes, sawing and drying techniques, prefabricated housing, and lumber grading.



## Forest Products Laboratory Research Priorities

1. Advanced Structures: New technologies referred to as mass timber provides the means to engineer taller wood buildings and enable much faster assembly of multi-story buildings.
2. 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.
3. 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.
4. Advanced Composites: New products, like wood-plastic composites, and potential products, like cellulose nanomaterial-reinforced composites, provide new lightweight materials for applications as varied as deck boards, lightweight vehicle parts, and lightweight armor.

## Forest Products Laboratory 2020 Research Highlights

Guide for selection and use of pressure-treated wood

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

Comparing juvenile wood depictions in the literature to wood property maps generated for mature longleaf pine trees  
 Juvenile wood in the southern pines is usually shown as a central core of wood surrounded by mature wood, the latter tapering down in thickness when moving from the base of a tree to its crown. This study addresses the degree to which different juvenile wood depictions presented in the literature are applicable to a sampling of 70-yr-old longleaf pine (*Pinus palustris* Mill.) trees.

Juvenile wood (corewood) has been widely studied given its high contribution to the wood resource, especially for usable timber obtained at short rotation ages. Reviews of juvenile wood in the literature provide insight into its physiological origin, anatomical features, chemical/physical/mechanical properties, and utilization. Several illustrations of juvenile wood in pines have been generated to explain the variability in the aforementioned properties in a typical pine tree stem.

The present study addresses the degree to which different representations of juvenile wood are applicable to a sampling of 70-yr-old longleaf pine (*Pinus palustris* Mill.) trees. Wood property maps were derived from X-ray densitometry data gathered from tree disks taken at every 61 cm along each tree bole. Altogether, the wood property maps and data comparisons suggest that the more complex illustrations of juvenile wood appear to align with the study trees, attributable, in part, to their maturity and near maximum attainable height.

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

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

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

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

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

This study updated the estimate of the EKC model of forest area using sets of panel data capturing historical and the most recent socioeconomic trends and use. It then uses the updated model to evaluate how total forest area in 168 countries would develop over the next 100 years under alternative assumptions of economic and demographic changes. The econometric analyses showed that aggregate global forest area would increase by 7% in SSP3 (a future with the lowest rate of economic growth) to as much as 36% in SSP5 (a future with the highest rate of economic growth) by 2100 relative to 2015 levels. By evaluating the projected forest area trends globally and across major world regions, under alternative future scenarios of economic and demographic changes, this study gauges the usefulness of the estimated EKC model in providing a plausible projection of forest area that will be needed in future studies and/or policy simulations employed in global forest sector models.

#### **Maleic acid hydrotropic wood fractionation at atmospheric pressure**

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

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

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

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

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

### **Evaluating fire performance of adhesives used in CLT**

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

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

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

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

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

### **Durable, cost-effective timber bridges**

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

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

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

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

To provide this needed information, we developed synchrotron-based X-ray fluorescence microscopy (XFM) as an experimental tool to measure time-dependent concentration profiles of inorganic ions diffusing through individual loblolly pine (*Pinus taeda*) cell wall layers. Ions were locally applied using either KCl or CuCl<sub>2</sub> aqueous salt solution microdroplets and experiments were performed under 70%, 75%, or 80% relative humidity (RH). An analytical model based on Fick’s second law for diffusion was used to calculate diffusion constants.

Results revealed that diffusion rates increased with RH, the larger Cu<sup>2+</sup> diffused more slowly than the K<sup>+</sup>, and the Cl<sup>-</sup> diffusion constant was the same as that for the counter cation, indicating cations and anions diffused together to maintain charge neutrality. This more complete, quantitative description of diffusion in wood cell walls will enable optimization of cell wall diffusion processes for specific end uses and accelerate utilization of wood resources to meet our societal needs.

### **Role of leaf litter in above ground wood decay**

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

## **Investigating the role of moisture in durability of acetylated wood**

Acetylated wood is the most common form of modified wood in the world and is gradually gaining acceptance in the United States as a form of wood protection. Acetylated wood is less prone to dimensional shrinkage and also exhibits increased resistance to fungal attack. The exact mechanisms of fungal resistance are not fully understood but have been a focus of the bio-deterioration research community for several decades.

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

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

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

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

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

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

## **Seeing is believing: Finding the right enzyme for the job**

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

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

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

The rapid self-assembly of nanocellulose and nanochitin, was harnessed to produce high-efficiency and versatile biohybrid hydrogel (BHH) and aerogel (BHA) for water purification. The self-assembly process was driven by the electrostatic force between negatively charged TEMPO oxidized cellulose nanofiber (TOCNF) and positively charged partly deacetylated chitin nanofiber (PDChNF). The TOCNF were extracted from wood at the Forest Products Laboratory and the PDChNF were extracted from shrimp shells, a waste product. Self-assembly took place spontaneously at room temperature and without adding any crosslinking agents throughout the process. The assembled network results in the three-dimensional (3D) BHH that is physically cross-linked via both electrostatic interactions and hydrogen bonding between TOCNF and PDChNF. This network was freeze dried to obtain the BHA that exhibits a highly porous interconnected structure with a specific surface area of 54 m<sup>2</sup>/g. This structure is ideally suited for adsorption of toxic metalloid ions and organic pollutants due to the availability of its internal active sites.

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

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

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

Researchers at the Forest Products Laboratory and University of Wisconsin-Milwaukee created composites consisting of cellulose nanofibrils and Terfenol-D magnetostrictive particles. Various constructs of the materials were created, including laminating multiple layers with and without magnetostrictive particles. Magnetostrictive particles were also oriented in various configurations during fabrication. The effects of laminates and particle orientation on the magnetostrictive (in which a magnetic field creates shape changes) and Villari (change in magnetic properties due to stress) were examined. Composites containing particles with in-plane alignment had the greatest sensitivity to magnetic field for actuation but the lowest performance for stress sensing or energy harvesting applications. Composites with additional CNF layers exhibit markedly improved sensitivity in Villari experiments.

### **Rapid production of high- strength and translucent cellulose nanofibril sheets**

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

### **Gene conservation among lignocellulose-degrading fungi**

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

Addressing this question, scientists sequenced the genomes of *Pycnoporus cinnabarinus*, *P. coccineus* and *P. sanguineus* and compared their gene content, transcriptomes and extracellular proteins. The genetic repertoires were strongly conserved irrespective of geographic and climatic origins, and a core set of degradative enzymes were identified. Co-occurrence of extracellular H<sub>2</sub>O<sub>2</sub>-generating enzymes with H<sub>2</sub>O<sub>2</sub>-consuming enzymes were observed in the three species, although certain transcript pairs were independently regulated. The data also suggested synergism between cellobiose dehydrogenase-coding genes and at least one lytic polysaccharide monooxygenase gene. This study highlights a conserved core of fungal enzymes underlying mechanisms of lignocellulose degradation.

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

Global demand for renewable and sustainable materials such as wood products is growing. To support growth, a scientific approach is necessary to illustrate the environmental benefits of wood products. This report provides a detailed cradle-to-gate life-cycle assessment (LCA) and update to the environmental impacts associated with redwood (*Sequoia sempervirens*) lumber production in the United States. The results illustrated that redwood lumber production has a very low carbon footprint (37.97 kg CO<sub>2</sub>e/m<sup>3</sup> of lumber) and stores carbon about more than 18 times compared with its cradle-to-gate carbon footprint.

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

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

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

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

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

### **Approval of cross laminated timber shear wall system in US codes**

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

CLT offers many advantages such as the potential for mass production, prefabrication, speed of construction, and sustainability as an environmentally friendly and renewable construction product. Good thermal insulation, acoustic performance, and fire ratings are some additional benefits of the system. Despite these advantages, the lack of a current design approach is one of the challenges inhibiting widespread adoption of CLT in North America.

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

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

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

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

## **6.7. Forest Service Decision Support Tools and Data**

A decision support tool (decision support system (DSS)) is a computer-based information system that supports business or organizational decision-making activities. Decision support tools serve the management, operations, and planning levels of an organization (usually mid and higher management) and help people make decisions about problems that may be rapidly changing and not easily specified in advance—i.e., unstructured and semi-structured decision problems. Decision support systems can be either fully computerized, human-powered, or a combination of both. All aspects of forest management, from log transportation and harvest scheduling to sustainability and ecosystem protection, have been addressed by modern decision support tools. In this context, the consideration of single or multiple management objectives related to the provision of goods and services with tradeoffs that need to be factored into decision-making. The Forest Service's Community of Practice of Forest Management Decision Support Systems (<http://www.forestdss.org/>) provides a large repository of knowledge about the construction and use of forest Decision Support Systems.

The U.S. Forest Service currently reports 69 decision support tools. Some examples are:

- T9ree) - T is a forest simulator developed from biological as well as economic sub models for individual trees. T is designed to simulate alternative treatment schedules for all compartments in a planning area.
- LANDIS Landscape Disturbance and Succession model - LANDIS is designed to model forest succession, disturbance (including fire, wind, harvesting, insects, global change), and seed dispersal across large (>1 million ha) landscapes.

- **RODPOST** - RODPOST is applied for optimizing the assortment distribution of single trees, based on information about the length and diameter of the log.
- **[Invasive Plants in Southern Forests App](#)** - This app provides information on accurate identification of the 56 nonnative plants and groups that are currently invading the forests of the 13 Southern states. Recommendations for prevention and control of these species are provided.
- **[FMPP](#)** - The Forest Management Planning Package is an existing planning system used in practical forestry in Sweden. It focuses on the economically effective resource management of forest timber. The FMPP integrates economic theory, objective inventory measurements, growth forecasts and optimization methods. It is essentially aimed at long-term (strategic) planning of larger forest holdings. The planning problem can be formulated and solved in two ways: (1) A non-linear objective function and mathematical optimization result in a compromise between maximization of economics benefits (Net Present Value) and a sustainable development (sustained net-revenue profile); and (2) A linear programming package, JLP, is utilized to maximize Net Present Value under some preselected restrictions.
- **[EMDS](#)** - The system provides decision support for landscape-level analyses through logic and decision engines integrated with the ArcGIS geographic information system. The NetWeaver logic engine evaluates landscape data against a formal logic specification designed in the NetWeaver Developer system, to derive logic-based interpretations of ecosystem conditions. The decision engine evaluates NetWeaver outcomes, and data related to the feasibility and efficacy of land management actions, against a decision model for prioritizing landscape features built with its development system, Criterium DecisionPlus (CDP). CDP models implement the analytical hierarchy process, the simple multi-attribute rating technique, or a combination of the two methods. The system has been used in a high variety of applications.
- **Agflor** - This tool helps access the impacts of policy changes on regional land use patterns. It was used by Portuguese Ministry of Agriculture Regional Office of Alentejo (DRAPAL) to assess the impacts of common agricultural policy changes on agricultural and forestry activities on regional land use patterns over an area extending over 2 million hectares.
- **[Forest Vegetation Simulator \(FVS\)](#)** - Forest Vegetation Simulator (FVS) is a family of forest growth simulation models.
- **[Fuel Characteristic Classification System, Version 3.0](#)** - The system predicts surface fire behavior including reaction intensity, flame length, and rate of spread; and surface fire behavior, crown fire, and available fuel potential using a 9-point index.
- **The Hot-Dry-Windy Index improves fire weather forecasting** - A new tool helps fire managers anticipate when wildfires could become erratic or dangerous.

## **Data – Forest Service Research Data Archive (FSRDA)**

FSRDA was created in 2010 to publish and preserve digital scientific data collected from studies funded by FS Research and Development ([FS R&D](#)) and the interagency Aldo Leopold Wilderness Research Institute ([ALWRI](#)). In 2012, our scope expanded to the interagency Joint Fire Science Program ([JFSP](#)). To date, ~30% of our publications are from JFSP-funded studies. In 2019, we started a pilot project to provide publishing support for USDA APHIS' National Wildlife Research Center. FSRDA actively works with the network of FS experimental forests, ranges, and watersheds (EFRs) to publish and preserve the highly valuable data from their long-term studies. This work frequently involves converting paper-based historical data into modern digital formats and assembling metadata on the data from study notes, interim reports, and scientific articles.

FSRDA released 85 new data publications in FY2020. Data publication downloads increased 28% relative to FY 2019. This is the ninth straight year of substantive increases in our customer base. Interest in western wildfires was reflected in strong interest in FSRDA data publications describing wildfire occurrence and wildfire hazard potential. This interest appeared as downloads and use of these publications on third party websites that presented value-added content. FSRDA staff help to coordinate the availability of Forest Service R&D-created datasets to National Forest System users via the FS Enterprise Data Warehouse (EDW). The FSRDA staff also have Google Analytics information on where FS customers come from and, based on user data, publications are being used by the private sector for determining insurance premiums (fire occurrence dataset), by higher education as part of data science training, and by various state and local governments. (For example, the State of New Mexico's web site presents fire data from one of the FSR publications.) They also provide digital support for some of the agency's most popular articles (the most-downloaded article from Treesearch is a compilation of timber statistics); FSRDA staff published a companion publication that puts the table information in Excel format for easier analysis and re-use. It's not the most popular publication – that would be the fire occurrence dataset – but it will be in the top 10 when all usage is analyzed.

FSRDA staff have a leadership role on the team guiding the Forest Service transition to the ISO geospatial metadata standard. This supports FS compliance with a USDA departmental directive and with the Geospatial Data Act of 2018.

## 6.8. Who Owns the Forest?

Contrary to popular belief, nearly two-thirds of forests in the conterminous U.S. are privately, not publicly, owned. The distribution of ownership is 43 percent family, 28 percent federal, 16 percent corporate, 7 percent state, and 4 percent other private land (which includes Native American tribal ownerships). By showing the distribution of forest ownership, the *Forest Ownership Map of the Conterminous United States*, developed by the Northern Research Station, promotes the development of policies that support the conservation and wise management of public and private forests.



## 6.9. State & Private Forestry

Encompassing two thirds of America's forests, state- and privately-owned lands provide public benefits such as clean air, clean water, wildlife habitat, outdoor recreation, and most of the nation's wood supply. These forests face many threats, including wildland fire, invasive species, pests and disease, and the permanent loss of working forest land to non-forest uses. The Forest Service State & Private Forestry (S&PF) division helps ensure that forest landowners have the best technical, educational, and financial assistance available to achieve their unique objectives and to keep forests working for all of us. Below are just a few examples of S&PF Technology Transfer projects carried out in FY 2019

### Tribal Relations

The Tribal Connections Viewer (<https://www.arcgis.com/home/item.html?id=91a950377c264b7e84415ef2e91c3a49>) is a new geographic information systems tool available to Forest Service staff, tribes, and others that provides a visual, interactive map identifying Forest Service-administered/owned land, tribal lands, and ceded lands all in one place. Nearly 4,000 miles of shared boundaries between tribal lands and Forest Service-administered/owned land are identified. Like never before, Tribes and the Forest Service can now engage in shared land management activities across administrative boundaries and at larger landscape scales.

The Tribal Connections Viewer improves data-based decision making on incidents and in resource management for both tribes and the agency; encourages meaningful consultation and collaboration with our tribal partners; shares technology and knowledge across boundaries and borders; honors treaty rights and the federal trust responsibility; and identifies opportunities for new and expanded partnerships between tribes and the agency or collaboration on conservation projects and programs, using the best data available.

The Tribal Connections Viewer uses the most current data available from the U.S. Census Bureau, Forest Service, Smithsonian Institution, and other sources to provide current and historical details, such as historic treaties, for each location on the map. Having this information easily available in one online resource will improve the efficiency of agency-tribal coordination, collaboration, and consultation. The online resource helps to promote sound management of protected areas through conservation efforts, capacity-building activities, and education initiatives. It does so through the creation of an interactive mapping tool that shows where and how lands managed by the Forest Service connect or overlap with current tribal trust lands. The accuracy of the tool is being continuously refined through input provided by users from tribal nations, who will note where corrections should be made, in comparison with their own local data.

### Wildland Fire

Wildfire season is year round and, regardless of where they start, wildfires impact thousands of wildland-urban interface communities. Helping communities in fire-prone areas prepare for wildfire reduces impact on those communities, has the potential to reduce suppression needs, and helps protect civilian and firefighter lives. Addressing the impacts of wildfire on communities is an "all lands/all hands" effort.

Community Fire Adaptation: Federal, state, and local governments partner with non-profits, fire departments, and other stakeholders to reduce wildfire risk locally through the use of mitigation best practices. The Forest Service has developed best practices to enable effective, efficient, and sustainable mitigation efforts locally. Those best practices are based on the best-available science, proven by experience on the ground, and shared with communities and partners nationwide.

Wildland-Urban Interface Research: The community wildfire risk reduction work the Forest Service and our partners share is based on science and verified by experience. Partners like the Joint Fire Science Program, the Insurance Institute for Business and Home Safety, the various Forest Service Research Stations, and Forest Service fire researchers form the

foundation of best practices. As an example, the Forest Service, states, and partners have long thought messaging through public service advertising, literature distribution, and social media was the route to mitigation actions on the ground. Research supported by experience has shown that it is not the case. Messaging may help people become aware of their wildfire risk, but it is not a key factor in spurring them to take action to reduce risk. That takes one-on-one, face-to-face engagement at the local level and building trusted relationships. Sharing that information in an effort to change our approach to community wildfire mitigation is key to accomplishing risk reduction on the ground.

The Community Mitigation Assistance Team (CMAT) concept was piloted in 2015 and is now a standing resource for communities impacted by wildfire. The teams use the teachable moment of smoke in the air, high fire activity, or high fire risk to work collaboratively with community leaders to share best mitigation practices, help form local mitigation partnerships or coalitions, and plan effective and efficient mitigation programs that can live on in the community long after a wildfire or the deployment of the CMAT. The CMAT has worked with communities and helped mitigation coalitions in association with the Bridger-Teton National Forest, Rogue River-Siskiyou National Forest, Pisgah National Forest, Pike and San Isabel National Forests, and the Okanogan-Wenatchee National Forest. The CMAT has also developed a stand-alone Community Mitigation Academy best mitigation practices course that is available to states or regions at no cost to share the most effective ways to reduce community wildfire risk and to build a local cadre to accomplish on-the-ground mitigation. See <http://nrfirescience.org/resource/13555>.

Working with Partners: Internal and external partners are key to getting work done in communities and to sharing the latest effective methods to accomplish risk reduction. An important long-term partner has been the National Association of State Foresters. In addition, we continue to increase technology transfer through important partnerships with career and volunteer fire departments nationwide. Work with the National Volunteer Fire Council helps share best practices for assessing homes and communities for wildfire risk and ways to share that information with residents: <https://www.nvfc.org/programs/wildland-fire-assessment-program/>. Another important partner, the International Association of Fire Chiefs (IAFC) supports the Ready, Set, Go! Program which focuses on readiness and situational awareness for safe and timely evacuation: <http://www.wildlandfirersg.org>. IAFC also supports the pilot Fire Department Exchange (FDX), which allows fire departments to share information about mitigation lessons learned and help one another improve on-the-ground wildfire risk reduction.

The FAC Learning Network, out of which grew the Fire Department Exchange, is a collaborative effort with the Forest Service, The Nature Conservancy and The Watershed Center. The FAC Learning Network's mission is to connect and support people and communities who are striving to live more safely with wildfire. The Network is a catalyst for spreading best practices and innovations in fire adaptation concepts nationwide. The purpose of FAC Net is to exchange information, collaborate to enhance the practice of fire adaptation, and work together and at multiple scales to help communities before, during and after wildfires: <https://fireadaptednetwork.org/>.

The Fire Adapted Communities Coalition was formed in 2009 and still functions primarily as a technology transfer information sharing effort between and among partners (and their individual audiences) engaged in community wildfire mitigation efforts (community fire adaptation). Coalition partners share the work they are doing to help communities reduce risk and their successes and work to collaborate for effectiveness and innovation across programs. Coalition members use webinars (recorded for later access), social media, videos, face-to-face learning sessions (also recorded), and workshops to share best practices. FAC Coalition members are the U.S. 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 provides technical assistance on forest health-related matters, particularly those related to disturbance agents such as native and non-native insects, pathogens, and invasive plants. FHP conducts aerial surveys, remote sensing, and aerial applications to assist federal and state partners and the public and to guide forest management actions to improve forest health. This effort makes scientific data available to land managers and states that can reduce the risk and impact of infestations. We work through partnerships across all lands, providing forest insect, disease, and invasive plant survey and monitoring information, and technical and financial assistance to prevent, suppress, and control outbreaks threatening millions of forested acres across the nation. Our monitoring program is designed to determine the status, changes, and trends in indicators of forest condition on an annual basis, providing data to guide land managers in maintaining, enhancing, and restoring healthy forest conditions. The FHP program uses data from ground plots and surveys, aerial surveys, and other biotic and abiotic data sources and develops analytical approaches to address forest health issues that affect the sustainability of forest ecosystems.

FHP recently completed a 2018 update of the National Insect and Disease Risk Map (NIDRM) and has facilitated transfer of these digital data to the States in support of the 2020 State Forest Action Plan updates. The NIDRM provides a nationwide strategic assessment of the risk (hazard of tree mortality) due to insects and diseases. Values “At Risk” in the NIDRM represent the expectation that, without remediation, 25 percent or more of the standing live tree basal area will die over a 15-year (2013 to 2027) time frame due to insects and diseases. The 2018 update depicts areas where recent significant tree mortality events have occurred, removing these areas from “At Risk” conditions. Since 2012, upon completion of the last NIDRM, major tree mortality events from forest pest outbreaks, fire, and broad-scale forest harvesting operations have reduced or, in some cases, eliminated risk. A major tree mortality event was defined as one or more of the following:

- Areas depicted as forest cover loss in the University of Maryland Global Forest Change dataset.
- Three or more years of mortality mapped in aerial detection surveys (ADS).
- In the Eastern U.S. only, three or more consecutive years of defoliation mapped in ADS.

The 2018 update does not account for increases in risk due to recent tree growth and density, which can make additional trees susceptible and vulnerable to new forest pest attacks.

NIDRM provides the following in support of State Forest Action Plans:

- A spatially explicit dataset of areas at risk for experiencing 25% or more tree mortality from insects and diseases through 2027.
- A critical portion of the timetable of forest health, by linking historical ADS data to future projections of forest pest mortality events.
- A baseline for monitoring the current and potential extent of new and existing forest insect and disease threats.
- Early identification of areas with potential for new forest health threats to help prioritize management activities and increase the affordability and effectiveness of control strategies.
- Improved communications and awareness of forest health threats.

## Urban & Community Forestry

The Forest Service has a long history—well over three decades--of delivering urban forestry research, technology, and information to our partners, stakeholders, and customers. In FY 2019, the Urban & Community Forestry Program provided technical or financial assistance to more than 7,755 communities across the United States. Sharing agency knowledge and tools is essential to improving the management and long-term sustainability of urban ecosystems. Our partners and customers, including 63 state and territory forestry agencies, more than 35 national partners, more than 150 community tree groups, private industry, academic institutions, and municipalities, are asking the agency to continue providing much-needed science and technology delivery services. This demand is increasing as our audience and customer base expands to new user groups such as public works, planning, sustainability, and public health and safety professionals. The demand is also evolving as we aim to be more effective in reaching a diverse audience in communities of all sizes, and as information sharing becomes more essential. To best serve our customers, the FS formed the Urban & Community Forestry Technology and Science Delivery (TSD) Team in 2014. This team is made up of S&PF Urban & Community Forestry program managers and FS Research & Development personnel from around the country. The group's focus is on ensuring our urban forestry staffs are strategic, skillful, creative, and nimble in our science delivery efforts. The team employs a contemporary technology transfer approach in order to reach our diverse audiences, and to coordinate across deputy areas, regions and stations to ensure that we are sharing information that is timely, relevant, and easy to access, understand, and use.

For example, through a grant from the Urban & Community Forestry Program, the team partnered with American Forests and the National Association of Regional Councils to launch the [Vibrant Cities Lab](#) web platform to help policymakers, municipal executives, and urban forestry practitioners make science-based decisions about the trees that make their community healthier and more livable. Hosting more than 25,000 users to date, this platform provides curated summaries of the best available science in urban forestry and a toolkit and self-assessment that guides users as they work to improve urban forest plans and practices. In FY2019, Lab advancements under development included a resilience section adapting Forest Service publications on storm readiness and response; a community-centered tool for prioritizing the most important urban forestry investments; and a funding finder tool on the website to help secure funding for urban forestry projects. Upcoming advancements include a toolkit to identify the complex barriers low income people of color face in entering and sustaining careers in the tree care industry, as well as provide proven or innovative solutions. Adapting this publication into an online action guide on Vibrant Cities Lab will transform the site from a passive resource of information about jobs into a dynamic, interactive tool to help address some of the most pressing issues faced by disenfranchised populations and an industry seeking to fill a labor shortage.

## Wood Innovations in Building

Wood may be one of the world's oldest building materials, but it is also now one of the most advanced, and the Forest Service is playing a critical role in providing assistance to state, tribal, local, and private entities on how to incorporate wood as a green building material. By building stronger markets for innovative new wood products, we are supporting sustainable forest management, helping to reduce greenhouse gas emissions, and putting rural America at the forefront of an emerging industry. One key avenue for providing technical assistance around the use of wood in building is through

our partnership with WoodWorks. WoodWorks, an initiative of the Wood Products Council, provides free, one-on-one technical support to architects and engineers on wood building design. Through partnerships with the Forest Service, major North American wood associations, and other organizations, WoodWorks promotes the construction of wood buildings. The \$2 million contributed by USFS in 2017 leveraged an additional \$4.5 million from the wood industry and Canadian government, allowing significantly greater impact than could have been achieved independently. WoodWorks provides technical expertise on a wide range of building types, including schools, mid-rise/multi-family, commercial, corporate, franchise, retail, public, institutional, and more. WoodWorks hosts yearly conferences across the country and provides workshops and training opportunities on a range of topics to expose architects and engineers to wood design. In FY2017, WoodWorks has directly or indirectly influenced the use of wood in over 500 buildings.

## **Owner Assistance**

The FS cooperates with researchers and partners to understand landowner behavior and develop technical assistance programs that meet the interests and management needs of America's non-industrial private forest landowners. Through investments in the National Woodland Owners Survey, the Reforestation Nurseries and Genetic Resources program (RNGR), National Seed Lab, and the National Agroforestry Center, State & Private Forestry advances technology transfer. RNGR, a unique and innovative collaboration across deputy areas, provides science-based technical expertise to 1400 native plant nurseries. RNGR helps plant professionals respond to ever-increasing demand for high-quality, ecologically appropriate plant materials to address climate change, invasive species and pests, habitat loss, and post-wildfire restoration. In addition, RNGR employs contemporary technical transfer approaches to reach diverse audiences including federal, state, private, tribal, and international professionals through webinars, Native Plant Propagation Protocol database, Tree Planters' Notes (international applied journal focused on plant production and establishment), and website with over 70,000 downloads annually of articles pertaining to reforestation, restoration, and native plant production.

Forest Legacy (FLP), Community Forests and Open Space (CFP), Landscape Scale Restoration, and Forest Stewardship (FSP) programs ensure information sharing on forest management and conservation is timely, relevant, and easy to access and use for partners, including federal, state, and local agencies, tribes, non-profit organizations, and university extension programs. The Forest Legacy program has online implementation tools and is developing a resource library for states and other partners. FLP also supports the Land Trust Alliance's Learning Center that provides critical permanent forest land conservation information through online resources, webinars, and courses to over 900 land trust organization members.

In FY2019 FSP, through state forestry agencies, provided technical assistance to over 602,000 private forest landowners. Through a partnership with the Forest Service, Yale University's Tools for Engaging Landowners Effectively (TELE) helps federal, state, and local agencies, university extension, and non-profit organization staff to address complex conservation challenges using targeted marketing tools and techniques. Hosting more than 50 workshops in 39 states and Guam, TELE has trained more than 1,500 people representing over 500 organizations and leading to 15,000 landowners taking action on more than 730,000 forested acres. In FY2019, TELE developed online tools for natural resource professionals to foster peer-to-peer learning and streamline implementation of the TELE approach. Tools include marketing tips, lessons learned, a facilitator's guide, and a landowner engagement guide, a complete resource to designing landowner programs and communications.

## **Conservation Education**

Forest Service Conservation Education (CE) helps people of all ages understand and appreciate our country's natural resources and learn how to conserve those resources for future generations. Through structured educational experiences and activities targeted to varying age groups and populations, conservation education enables people to realize how natural resources and ecosystems affect each other and how resources can be used wisely. Through conservation education, people develop the critical thinking skills they need to understand the complexities of ecological problems. Conservation Education also encourages people to act on their own to conserve natural resources and use them in a responsible manner by making informed resource decisions. FS Conservation Education is part of the advisory board of the CE-Works project, developed by the North American Association for Environmental Education and Stanford University, and designed to demonstrate the impact and value of environmental education by substantiating powerful anecdotes from across the field with empirical evidence. The project is conducting comprehensive literature reviews that demonstrate the impact of environmental education on key environmental and social outcomes and is translating findings into communication tools to benefit the field.

For more than a decade, Conservation Education has partnered with Prince William Network to bring nature learning to classrooms through technology, including webcasts and webinars, and hosting online education materials. Under the FSNatureLIVE banner are numerous "LIVE" projects, each arranged around a theme and housed in a dedicated website, complete with broadcast links, associated curriculum and classroom grant opportunities. Recent projects include FreshWaterLIVE, WetlandsLIVE, and GrasslandsLIVE.

The Latino Legacy Youth Leadership in Nature Challenge and Green Ambassador model is an outdoor leadership training program that hosts approximately 20-25 diverse youth per session. The program serves first- and second-generation

students of diverse ethnic backgrounds. This week-long connection with nature and natural resource career opportunities has provided visits and one-on-one networking with major Hispanic Serving Institutions, state universities, agricultural colleges, and governmental agencies.

The Natural Inquirer publications focus upon 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 FS, engage youth in STEM education, and inspire youth to pursue science-driven careers. Scientist cards present information on specific FS scientists from many different backgrounds, and many of the cards, which inspire young conservation leaders in the pursuit of natural resource related careers, are translated into Spanish.

Partnering with the National Environmental Education Foundation, the FS reaches underserved children and their families through health care providers with prescriptions to recreate in parks and forests near their homes with an emphasis on underserved areas of the country. Over 880 health care providers have been trained about the health benefits of nature and have written over 1000 Prescriptions for Outdoor Activity. They have also created digital applications for outdoor activity to help motivate technology-bound children to get outside.

## 6.10 Water

National forests are the most important source of water in the United States. The annual value of water flowing from agency lands has been estimated to be \$7.2 billion. More than 60 million Americans—including residents of cities such as Atlanta, GA; Denver, CO; and Portland, OR—rely on drinking water that originates on national forests. In a sense, the Forest Service is the Nation's largest water company.

Forests provide people with clean, reliable drinking water. But these waters are at risk due to the needs of growing human populations, continued conversion of forests to other land uses, and anticipated changes in climate conditions. Given such threats, it is important to understand how much drinking water originates in forests, which populations and communities are served, and how best to regulate water quality through proper watershed management.

- A [Rocky Mountain Research Station](#) study published in 2015 showed that forests yield 46 percent of the mean annual water supply but occupy only 26 percent of the land area of the contiguous U.S.
- A [2014 report](#) published by the [Southern Research Station](#) showed that clean water begins in national forests for over 19 million people in the South—roughly the population of Florida. The report provides information at a level not previously available on the amount of surface drinking water provided by national forest lands to communities in the South. This information can help support partnerships among state, federal, and nongovernmental organizations that work to conserve the forest cover that provides the area's clean, dependable water supplies.

### How Forests Provide Clean Water

Small headwater streams determine the water quality of the larger rivers, lakes, and reservoirs that they flow into. Researchers used data from Hubbard Brook Experimental Forest to study the pathways water takes from the time it lands as rain until it reaches a headwater. By tracing water isotopes, they found that the median time it takes rain water to reach a stream ranges from 50 days during wet periods to 190 days during dry periods. The team took it one step further and measured changes in the concentrations of dissolved substances that naturally occur in water, such as calcium, and are often what make water “hard” or “soft.” They found that not only does the amount of time water spends flowing through forest soils determine how much a forest filters the water and removes dissolved substances, thereby impacting water quality, but also what path the water takes through the ground. Research like this could potentially help land managers target specific areas of a forest that provide the most filtration services for restoration or conservation to improve a forest's water filtering capabilities.

### Best Management Practices Improve Water Quality and Save Money

Whether developing camp sites for visitors or restoring stream habitats, work on national forests often involves disturbing the ground, which creates opportunities for sedimentation and other negative water quality impacts. Best management practices are techniques that help control and reduce water pollution and protect aquatic ecosystems.

Forest Service scientists pioneered the first national program to strengthen implementation and monitoring of [best management practices \(BMP\) used to protect water quality](#) from the diverse range of ground disturbing and management activities that occur on national forest system lands. The national BMP monitoring program provides consistency for evaluating BMP implementation and effectiveness across all National Forest System units, which, in turn, allows the Forest Service, for the first time ever, to report national performance results to regulatory agencies, states, tribes, other stakeholders, and the public. The consistency of the monitoring program is expected to result in improved water quality and millions of dollars of savings through simplified and streamlined monitoring approaches that contribute to the success of both local and national adaptive management strategies.

## 6.11 2019 Fire & Fuels Technology Updates Fire and Aviation

The results of Forest Service fire research help society address the on-going challenges of living with wildland fire.

### Background

“Science Serving Society” is the motto for USDA Forest Service Research & Development. Forest Service fire scientists, analysts, and technology transfer specialists work to put science in the hands of managers, decision makers, policy makers, homeowners, and communities.

The results of Forest Service fire research come in many forms, from user-friendly software and data to real-time support trained analysts on active wildfires, to educational materials for school children.

### Research Highlights

Smoke forecasting systems:

Even low-intensity prescribed fires can have adverse effects on air quality and human health. Smoke modeling tools integrate meteorological data, cutting edge smoke science, and fire behavior predictions to help fire managers schedule essential prescribed burns to minimize these health impacts.

Decision support for treating wildland fuels:

Forest Service research provides methods to answer questions such as: Which communities are most at risk to fire? What fuel treatments will be most effective at reducing the risk of severe fire? How can forests be restored to a healthier condition where fire plays a positive role? How and where should scarce funds be best invested to reduce the negative consequences of fire? Fire and fuels research provides the scientific foundations to a National Cohesive Wildland Fire Management Strategy, a cross-jurisdictional strategy to restore resilient landscapes, create fire-adapted communities, and respond to wildfire.

Smoke Updates

Airnow - [Airnow Link](#) used by Air Resource Advisors to model and create public smoke forecasts, compliant with S.47 Dingle Act of 2019.

Monitoring 4.1 - [Monitoring Link](#) 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 - [Landfire Link](#) - updating of LANDFIRE layers and development of analysis tool.

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

## 6.12 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; non-governmental interest groups; investors; and private firms. IMAR work focuses in four areas: 1) Forest Inventory and Analysis Program (FIA); 2) Resources Planning Act (RPA) Assessment; 3) Sustainability Assessment; and 4) Remote Sensing and Geospatial Analysis Research. In partnership with Forest Service International Programs, IMAR also provides leadership and coordination for international monitoring and assessment activities to the United Nations Food and Agriculture Organization's (FAO) Global Forest Resource Assessment, the FAO North American Forestry Commission, the United Nations (UN) Economic Commission for Europe Committee on Forests and the Forest Industry, the UN Forum on Forest, the Canadian Forest Service, and various U.S. agencies for international development activities.

## Forest Inventory and Analysis Program

Since 1930, the Forest Inventory and Analysis (FIA) program has been building the largest continuous dataset on forest resources in the world. Through consistent inventory processes, FIA data are widely used to address local and regional issues related to trends in forest extent, health, and productivity; land cover and land use change; the changing demographics of private forest landowners; and industrial and non-industrial uses of timber. Forest inventories have expanded their primary supporting role in decision making from forest products and economic development in the last century to a wider range of ecosystem services today, including carbon, water, recreation, wildlife habitat, biodiversity, and human health. Hundreds of public and private entities – from state forest agencies to academic institutions to timber management companies – rely on FIA to generate authoritative protocols and data, conduct applicable research, and operate businesses.

The FIA program conducts forest inventories in all 50 states and U.S. territories. Field plots have been collected on approximately 90 percent of the U.S. forestlands, with the remaining 10 percent in parts of interior Alaska yet to be surveyed. Although plot-based field surveys provide information concerning existing forest conditions, additional surveys such as the [timber product output \(TPO\)](#) provide information on commercial product generation and the [National Woodland Owner Survey \(NWOS\)](#) on the characteristics and management objectives of the Nation's private woodland owners.

## Resources Planning Act Assessment

Leads the Resource Planning Act (RPA) Assessment, which conducts research on the current status and trends and projected futures of forest and rangeland renewable resources. The RPA Assessment is mandated by the Forest and Rangeland Renewable Resources Planning Act, covering resources on all ownerships. The assessment examines how the interaction of socioeconomic and biophysical drivers affects the productivity of forest and rangeland ecosystems and their ability to meet increasing demands for goods and services, including analyses of forests, rangelands, forest products, wildlife and fish, biodiversity, water, outdoor recreation, carbon, land use, and urban forests.

## Sustainability Assessment

The Sustainability Assessment program conducts research on criteria and indicators of forest sustainability to provide a comprehensive evaluation of forest conditions in the United States as they relate to the ecological, social, and economic dimensions of sustainability. Forest sustainability is directly tied to the Forest Service's core mission, and understanding whether forests are sustainable at the national level is important because such understanding is needed to guide national policy formulation, it can take a long time to improve forest conditions, and trade of wood products domestically and internationally increasingly expects sourcing from sustainable forests.

The United States is updating its National Report on Sustainable Forests, last compiled in 2010. The report uses a criteria and indicators framework (The Montréal Process Criteria and Indicators) for describing forest conditions and their associated values, characterizing the essential components of sustainable forest management. These internationally agreed-upon criteria and indicators were developed collaboratively with other Montreal Process member countries as a shared response to the pressing need for sustainable forest management.

## Remote Sensing and Geospatial Analysis Research

Emerging remote sensing datasets and technology advancements are foundational to increasing the FIA program's efficiencies and meeting broader user needs. These efforts are also central to implementing Section 8632 of the 2018 Farm Bill, which directs the agency to continue to increase efficiencies in the operations of the FIA program through the use and integration of advanced remote sensing technologies, as well as through partnerships in this arena. Using remote sensing, National Forest Inventory precision targets can be resolved at a smaller landscape scale, typically resulting in better forest inventory estimates and translating into cost savings. Currently, free and public satellite data, such as from the USGS-NASA Landsat constellation, and data from the National Agriculture Imagery Program (NAIP), are used to complement FIA activities. Airborne and satellite Light Detection and Ranging (LiDAR) are remote sensing technologies that are increasing FIA's data collection efficiencies in remote or inaccessible areas. LiDAR and stereo digital imagery offer great potential but require higher skillsets and greater storage and computational needs. Advances in machine learning and GIS technology have partially addressed these challenges and improved efficiency of FIA estimation procedures.

## FIA Leads Implementation of Policy Change on Agreements

In FY2020, the FIA program adopted changes to ensure that confidential information annually collected through the program's surveys on field plots, landowner characteristics, and timber product output from mills, was protected to the full extent of existing laws when entering into agreements with third parties. In addition, revising the traditional way of entering into formal partnerships ensured the acknowledgement and recognition to FIA of all products and derivatives built from FIA data and produced by third parties. In addition to best protecting FIA assets, this policy change also would demonstrate to our partners and clients the extent of their investments in products produced in partnership with

other institutions. These objectives led to the search for legally binding instruments and a revision of long-established agreement practices as the new way to conduct business.

In an effort to protect 325,000 plot locations across 50 states and U.S. islands, landowners' personally identifiable information, non-public corporate data, and unpublished information, FIA adopted the use of Material Transfer Agreements (MTAs) and Cooperative Research and Development Agreement (CRADA) as the exclusive agreement types to sign when transferring FIA confidential data to a third party. FIA also adopted the use of the Memorandum of Agreement (MoA), replacing the previously used overarching instrument, the Memorandum of Understanding (MoU), because the legally binding nature of MTAs, CRADAs, and MoAs holds parties accountable for the commitments and terms established in these conditional agreements.

FIA's efforts to protect the program has led to a permanent policy change in the Forest Service Handbook, which defines the agency's official protocol for the use of MTAs and CRADAs by the entire Forest Service. We anticipate that more FS programs will follow FIA's pioneering steps in the adoption of these legally binding instruments when entering into agreements with third parties as a way to ensure that agreed terms are met, to better clarify responsibilities among parties, and to support these partnerships in the long term.

In 2020, FIA executed its first CRADA, with the Environmental Systems Research Institute (ESRI), as well as executed 20 new MTAs and 3 national MoAs.

## Recent Achievements by IMAR Staff and FIA Units Located at the Research Stations

- *Supplied over 240 spatial data requests and almost 4.5 million online data requests and responded to almost a thousand consultations, investing 7,764 hours of staff time* – Through [online applications](#), the [Spatial Data Service Team](#), and subject matter experts, FIA addresses the growing informational needs related to forest conditions, forestland ownership, and timber product generation.
- *Published the [estimated carbon loss](#) due to tree mortality caused by the most damaging non-native insects and diseases in U.S. forests* – This work demonstrates the value of FIA data to assess broad-scale changes in forests and indicates that forest pest invasions, driven primarily by globalization, are creating a large risk to U.S. forests and have significant impacts on carbon dynamics. Increased tree mortality from the impacts of alien insect and diseases results in the transfer of carbon stored in live trees into dead material, much of which will eventually return to the atmosphere. Results show that non-native forest pests threaten an estimated 76 percent of carbon sequestration in North America that comes from forests.
- *Increased awareness and use of FIA data by managers of national forests in several regions* – These efforts have enhanced national forest managers' understanding of FIA data and how to best use it in the management, project development, vegetation mapping, and broad-scale monitoring of the National Forest System. Published two related articles ([Wurtzebach, 2019](#) and [Hoover, 2020](#)).
- *Published the [analysis](#) of the causes leading to carbon stock changes across the National Forest System* – For the first time, baseline assessments of carbon stocks in every national forest incorporate detail on the causes of carbon stock change, including timber harvesting, insect outbreaks and diseases, aging, climate variability, increasing atmospheric carbon dioxide concentrations, and nitrogen deposition. Previous baseline assessments of carbon stocks evaluated observed trends based on forest inventory data but were limited in their ability to reveal detailed causes of these trends. Results support national forest units in assessing carbon stocks, quantifying carbon outcomes of broad forest management strategies and planning, and meeting carbon assessment requirements of the 2012 Planning Rule and directives.
- *Developed and [published](#) the theoretical basis for the NASA Global Ecosystems Dynamics Investigation (GEDI) mission's estimates of global forest biomass* – This research brings a new level of accuracy to understanding the role of forests in the global carbon cycle. Most uses of spaceborne LiDAR for biomass estimation have ignored formal modes of uncertainty estimation. GEDI is the first mission designed around forest sampling considerations. FIA scientists used specially collected field and airborne LiDAR data to test a hybrid model-based statistical estimator that GEDI will use globally.
- *Published the [analysis](#) of herbaceous species widespread vulnerability to atmospheric deposition of nitrogen and sulfur in the United States* – In collaboration with U.S. Environmental Protection Agency, universities, and the U.S. Geological Survey, FIA scientists found that about 70 percent of herbaceous species in the United States are at risk from atmospheric depositions of nitrogen and sulfur. Results from this analysis can inform improvements to air quality policies in the United States and globally.
- *Developed and published a [new method](#) using drones with lasers and aerial photos to complement field surveys in forest monitoring* – The new method aids forest inventories using advancements in photogrammetry and market sensors and platforms to incorporate an unmanned aerial systems-based approach into existing forest monitoring.

- *For the first time, estimated greenhouse gas emissions and removals from managed forest land in Alaska from 1990 to 2017*– Including all managed forest land in Alaska in the 2019 U.S. GHG inventory establishes important baseline estimates for this region, provides a more complete characterization of GHG emissions and removals in the United States, and helps identify opportunities for mitigating GHG emissions in Alaska and other remote areas with limited information. Managed forests in Alaska represent 10 percent of the total managed forest land area in the Nation, but store 17 percent of the total carbon in forests. These forests also represent a net carbon sink over the last 27 years but there is considerable interannual variability driven, in large part, by wildfire. Emissions from severe fire years in Alaska substantially reduce the contribution of U.S. forests as a carbon sink in those years.
- *Published a [methodology](#) to improve the inventory of mangrove forests in the U.S.* – In collaboration with NASA and Mexico's National Forestry Commission, FIA tested different methods for mangrove inventory in Florida. Results of this analysis offered solutions to overcome challenges related to ground measurements, including accessibility issues, time constraints, and hazardous conditions.
- *Published an [assessment](#) of the status of white oak advanced regeneration in forests of Kentucky and Tennessee* – The assessment provides a better understanding of white oak (*Quercus alba* L.) regeneration and will assist forest management decisions to decrease the risk of current decline of oak forests in the Eastern United States. Much of this decline can be traced to maturing forests (succession), species replacement, cutting, and ineffective fire management.
- *Published [reports](#) to support development of the upcoming RPA Assessment* – These reports examine the changing composition of the U.S. land base and establish plausible scenarios for future U.S. socioeconomic growth and climate change. This information sets the stage for resource analyses in the RPA Assessment.
- *Developed data [guides and catalogs](#) to help land managers use information from the RPA Assessment to support planning and decision making* – In particular, the catalogue will assist addressing the requirements of the 2012 Planning Rule by connecting the Planning Rule assessment topic areas and directives with relevant datasets, tools, reports, maps, and other information from the RPA Assessment.
- *Published national-scale forest [sustainability indicator reports](#) on biotic and abiotic forest disturbance, and on soil and water conditions on forest lands* – The published reports updated seven of the 54 indicators internationally agreed to by the Montreal Process, an international effort assessing sustainable forest management and providing a framework for describing the value and condition of participant nations' forests.
- *Completed [Voluntary National Report](#) from United States of America to the United Nations Forum on Forests 15* – Major contributor and source of information for reporting on progress toward the implementation of the United Nations strategic plan for forests 2017–2030, the United Nations forest instrument and voluntary national contributions.
- *Provided statistical reports for USDA Annual Agricultural Statistics Report, UN Sustainable Development Goals, and the UN Economic Commission's annual Joint Forest Products Questionnaire* – Of these, the UNECE work is the most extensive, involving annual collation and estimation of production and trade statistics for the U.S. wood products sector and all of its constituent product categories.

## A Role Model for Federal Accountability: The FIA Annual Business Report - BLOG

<https://www.fs.usda.gov/features/role-model-federal-accountability-fia-annual-business-report>

### Urban Sustainable Research

In dense urban centers, a city's treescapes (or lack thereof) have a big impact on the quality of life. A unique government and academic partnership uses Lidar and GIS technology to help communities map, assess, and monitor their urban tree canopy. <https://www.gisforscience.com/chapter11/>

### Baltimore Field Station

FS report on the financial and technical analysis for Baltimore City's Wood Sort Yard (funded by S&PF urban and community forestry) resulted this fall in an internal Baltimore City Innovation Grant for ~\$900k and will lead to 8 new jobs.

<https://www.fs.usda.gov/inside-fs/delivering-mission/deliver/baltimore-urban-wood-project-seeks-transform-waste-wood>

[http://baltimorewoodproject.org/pdf/FreshCut\\_BaltimoreUrbanWood\\_v3\\_2019.05.14.pdf](http://baltimorewoodproject.org/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 U.S. 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

**The FY2020 Effects of Drought on Forest and Rangelands of the United States:** *Translating Science into Management assessment builds upon the award-winning The Effects of Drought on Forest and Rangelands of the United States: A Comprehensive Science Synthesis.* The management synthesis was undertaken at the behest of the National Forest System, completed in a six-month timeframe with 50 authors from federal and state agencies and other experts. This innovative use of the IPCC approach has resulted in significant savings. To date, key assessments on climate change, drought, agroforestry, non-timber forest products, smoke, invasive species, genetics, and soils have resulted in \$7M in savings for R&D.

**The USDA Climate Hubs** provided outreach and technical support to federal employees and stakeholders through 76 webinars, 161 presentations resulting in 60,000 web site visits, 366 tribal engagements, and workshops engaging 6,802 participants. This outreach and support enhanced understanding of climate vulnerabilities and adaptation strategies and led to better integration of adaptation considerations into State Forest Action Plans in Connecticut, New Hampshire, and Michigan; identification of regional carbon sequestration strategies; creation of a regional drought learning network for the Southwest; and development of climate adaptation strategies for the Pacific Northwest.

**Addressing COVID-19 Pandemic Issues:** Co-signing an agreement among the Centers for Disease Control (CDC), Forest Service R&D, and State and Private Forestry, led to the development of a Smoke COVID Dashboard to better understand and communicate wildfire smoke and COVID-19 effects in communities during the 2020 wildfire season. In addition, we have led the effort in collaboration with the Department of Energy to leverage funding from the International Energy Agency Task 43 to investigate potential COVID-19 disruptions to the biomass supply chain for energy production in the United States.

**Forest and Rangeland Soils of the United States under Changing Conditions:** FS R&D released the newly published soils assessment on World Soils Day—December 5th. The book, *Forest and Rangeland Soils of the United States under Changing Conditions*, is an open access, multi-authored synthesis of leading-edge soils research, tools and technologies, and management strategies for the United States and affiliated territories. The U.S. Forest Service Research & Development-led science synthesis engaged 80 authors from 26 agencies and institutions addresses a broad range of subjects, and includes more than 1,000 reference citations. The book includes an overview of the state of forest and rangeland soils research in the United States and summarizes leading edge science regarding soil carbon, hydrology, biogeochemistry, and biological diversity and the effects of natural and human-caused disturbances.

**Library of Silvicultural Prescriptions and a Scenario Investment Planning (SIP) Tool:** We developed a Library of Silvicultural Prescriptions and a Scenario Investment Planning (SIP) tool that compares the benefits of specific prescriptions for forest resilience, fire adaptation, and economic impact objectives. The Forest Service is using SIP to set national investment priorities using the “Fire Shed Registry” approach, applying 250 silvicultural prescriptions covering over 300 million acres to inform the 3.5 million-acre NFS target to reduce hazardous fuels and improve forest conditions.

**Shared Stewardship:** We have strengthened regional implementation of agroforestry through regional agroforestry working groups across the United States. This included providing leadership and support for the Southwest Agroforestry Action Network (SWAAN), Pacific Northwest Agroforestry Working Group, Northeast/Mid-Atlantic Agroforestry Working Group, Appalachian Beginning Forest Farmer Coalition, the newly formed Southern California Agroforestry Working Group, and the American Forest Farming Council.

**Agroforestry Best Management Practices Developed:** We have developed protocols for the application of agroforestry best practices and improved stakeholder experiences in the forest farming community by developing new region-specific educational materials and producer profiles of agroforestry in states such as California, Wisconsin, Ohio, West Virginia, North Carolina, and Virginia. Despite a challenging year, we have made significant progress in assisting National Forests and the forest sector by providing leading-edge research to assist timber production through improved forest planning and by providing new research on best management practices for drought and soil management for improving productivity in both rural and urban landscapes.

**Climactic Variability and Change on Forest Ecosystems:** *A Comprehensive Science Synthesis for the U.S. Forest Sector*—a technical report for the U.S. Global Change Research Program National Climate Assessment. This publication provided the foundation for an award-winning book, *Climate Change and United States Forests*, which was edited by FS researchers and serves as a comprehensive science-based assessment of the effects and variability of a changing climate on U.S. forests to date.

**Tree Breeding and Forest Genetic Resources:** The first U.S. comprehensive assessment on Forest Genetic Resources of the United States of America will be published in early 2021 as the U.S. input to the U.N. Food and Agriculture Organization’s 2023 World Genetics Report. Authored by 60 national experts, the report supports the USDA Secretary’s vision for the Ag Innovations Agenda and strengthens USDA and private sector ties resulting in improved forest conditions, by providing access to public and private genetics tools and technologies, forest genetics innovations, tree breeding and management advances, and solutions to impacts from a changing condition.

**Heir’s Property Ownership Study:** Partnering with USDA Agencies, NGOs, the African American Land Retention Program and the Minority Landowner group, we completed a landmark study on the challenges surrounding heirs’ property ownership, especially those in underserved communities such as African Americans living in counties adjacent to national forests in the South and rural Appalachia.

**Climate Hub Publications:** The USDA Climate Hubs also produced 36 peer reviewed articles and 202 other articles for the public to enhance climate literacy and understanding of strategies to enhance forest, rangeland, farm and community resilience, including summarizing climate vulnerabilities and adaptation options for each of the national forests in the Southeast U.S., a Climate Change Primer for Forest Managers in the Sierra Nevada, and a guidebook on hurricane resiliency for pine forest landowners.

## Pending National Publications in 2021

Invasive Species in the Forests and Rangelands of the United States, to be published in 2021

Wildland Urban Interface: Forests and Rangelands in a Changing Environment, to be published in 2021

Wildland Fire Smoke in the United States: A Scientific Assessment, to be published in Spring 2021

## Landscape Restoration and Ecosystem Services Research

Landscape Restoration and Ecosystem Services Research (LRESR) conducts innovative and seminal research that provides sound science, innovative technologies, and practical applications to improve the health and productivity of our Nation’s forests and grasslands, inform natural resources policy and land management decisions, and anticipate emerging natural resource issues.

The Landscape Restoration & Ecosystem Services Research (LR&ESR) staff has leadership responsibility in the R&D mission area for five broad lines of inquiry:

- Providing renewable natural resource managers and policy makers with management and policy options that promote healthy, resilient, watershed conditions and wildlife and fish habitats.

- Designing new approaches to “green” investment and development that have lower impacts on the environment and that create sustainable economic development, increased employment, and healthy communities.
- Exploring how settings with trees all along the urban-to-wildland gradient create values for people—whether neighborhood residents or the recreation visitor—and how to practice more effective stewardship to enhance and sustain these values.
- Creating deeper understanding of how emerging technologies, products, and markets, along with changing economic and societal values, impact forests and the goods and ecological services they provide.
- Inventing wood-based materials that create new markets or expand existing markets, including inventing advanced manufacturing and conversion processes for utilizing woody biomass and recycled materials.

The prime objective for LR&ESR staff members across these five lines of inquiry is to build through syntheses and advocacy of field scientists’ findings a solid scientific foundation for natural resource management and policy-making at multiple spatial scales in boreal, temperate, and tropical forest ecosystems.

## Recent Achievements

**eDNAtlas:** The eDNAtlas is an open-access online database that provides precise spatial information on the occurrence and locations of aquatic species in the United States, as determined by eDNA sampling. The eDNA samples constituting the database are collected using a standardized field sampling protocol by numerous natural resource agencies and non-governmental organizations partnered with the USDA Forest Service National Genomics Center for Wildlife and Fish Conservation. The eDNAtlas database currently contains results from thousands of sites and dozens of species and will be annually updated with additional results for a growing list of species.

**Bat Genomics Database:** The US Forest Service RMRS National Genomics Center (NGC) is developing a Bat Genomics Database. The goals of this database are to create a national genomics repository for North American bat species for accurate species identification and to develop more sensitive Pd detection methods to trace origins of the fungal pathogen across the United States whether by natural dispersal or due to human assistance. NGC is also interested in developing the tools to collect bat and Pd eDNA from fresh watershed samples.

**Economic Valuation Protocol for Recreation:** Developed a scientifically valid protocol and data tables for calculating economic value of recreation on national forests, including a webinar and guidance document for training planners, managers, and specialists in the use of the method. The method is being rolled out this year.

**Timber Appraisal Methodology:** Developed a new method for timber appraisal to account for contemporary market conditions and prices so that fair market prices can be implemented to ensure positive bids and contract awards that generate timber revenue while improving forest health conditions. The method is under testing with positive results thus far.

**Urban Forest Connections:** Hosted nine webinars (<https://www.fs.fed.us/research/urban-webinars/>) that showcased research and best practices on topics ranging from integrating trees into stormwater management design to studying the impact of trees and green space on cardiovascular health. These webinars had an average of 214 attendees per session during the live webinars, and are available for download after the fact, reaching countless more practitioners.

**Illegal Marijuana Site Detection:** R&D scientists built a remote sensing model that can identify illegal marijuana grow sites from satellite imagery. They combined standard and novel technologies to “find the needle in the haystack.” Advanced image classification algorithms can sort a few hundred acres of illegal trespass grow operations from millions of acres. The system enables us to identify specific location coordinates of trespass grows and the detection of grow sites when it is not the growing season, making it useful to both law enforcement and ecological conservation priorities.

**Monarch Habitat Management:** Developed the technical transfer of materials concerning milkweed (*Asclepias* spp.) propagation and monarch butterfly waystation establishment, as well as field trials to determine feasibility of outplanting rhizomes of milkweed to support monarch butterfly populations. Monarchs cannot survive without milkweed; their caterpillars only eat milkweed plants, and monarch butterflies need milkweed to lay their eggs. Milkweed has been in decline in recent decades.

**e-Nose:** The electronic-nose (e-nose) is a relatively new diagnostic tool that has been used successfully for early detection of disease-associated biomarkers in certain human diseases. SRS researchers are working to adapt e-nose for early detection of animal disease pathogens such as *Pseudogymnoascus destructans* (Pd), the causative agent of white-nose syndrome (WNS) and the prions that cause chronic wasting disease (CWD). The e-nose is a non-invasive tool that conducts highly-specialized chemical analysis of infected animals before they show clinical signs of disease which could reduce the incidence of disease transmission.

**Bat-AMP and NABat:** PSW and SRS scientists have developed the Bat Acoustic Monitoring Portal (Bat AMP) and the North American Bat Monitoring Program (NABat Program), respectively, for monitoring the status of bat populations on the landscape over time. Both databases are collaborative efforts to share bat population data across multiple federal and state agencies.

**Improved Efficiency of Blister Rust Screening Technique:** White pine blister rust is an invasive pathogen that kills white pines, including the revered and high value Sugar pine. Years ago, PSW research discovered there is a major gene for resistance. A process was developed to screen seedlings to determine if the parent has the gene, and the technique has been used ever since to identify seed sources for reforestation; however, the process takes over a year, with only a 1-10% success rate. Recent genome sequencing research discovered 5 locations (markers) on the genome were potentially associated with the gene for resistance. Our research scientist realized the potential of these markers developed the markers, tested them, and demonstrated that 70-90% of the time the markers correctly identified resistant and non-resistant trees, allowing for candidate trees to be identified within one day and resistant seed sources to be identified with 100-fold efficiency.

## Knowledge Management and Communications

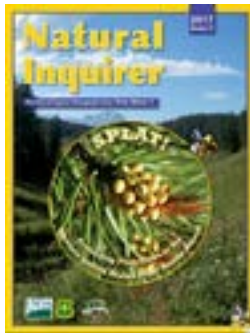
The Knowledge Management and Communications (KMC) staff's mission is to disseminate results of the agency's research to varied audiences—including the scientific community, land owners/managers, academics, policy-makers, the public and students—and to provide the information technology needed to disseminate results. KMC is responsible for leadership, development, oversight, and delivery of communications, performance accountability, science applications, science education, data quality, peer review, tech transfer and licensing activities and information management for Forest Service Research & Development. KMC also defines, develops, and maintains the national information architecture and content of databases essential to managing the strategic information flow and messaging about FS research.

- Plays a leadership role in the Forestry Research Advisory Council (FRAC) Federal Advisory Committee. Consisting of up to 20 members appointed by the Secretary of Agriculture from federal, state, university, industry, and nongovernmental organizations, the FRAC meets annually and presents recommendations to the Secretary on the Forest Service R&D program.
- Provides information technology resources for communicating research, including the R&D website, which provides public access to more than 50,000 scholarly publications authored by R&D scientists and collaborators.
- Maintains databases of research and archives information.
- Develops and disseminates science applications.
- Manages R&D data quality, peer review, and performance accountability.
- Manages R&D patents, licensing, and technology transfer.
- Manages the Forest Service History Program.
- Produces the Natural Inquirer, a free science education journal for students.
- Manages R&D's science delivery and communications program, which produces products and services that target varied audiences, including the scientific community, land managers, policymakers, the public and other stakeholder groups; this work involves overseeing the strategic planning and production of web and hard copy communications products, new outreach products, communications promoting the rollout of major R&D initiatives, and the translation of technical information into reader-friendly language.

## Recent Achievements

- R&D WO Newsletter: Produced 12 monthly newsletter issues on time. Recruited 1,660 new subscribers in 2018, including leaders in the Forest Service and partner organizations and Congressional staffers. Currently have about 11,000 subscribers. Infographics featured in newsletter are multi-purposed and are among the Office of Communication's most popular social media features.
- Rollouts of Reports: Wrote communication plan for agroforestry report and helped execute plan, which helped agroforestry report score in top 5 percent of all research outputs rated by Altmetric. Wrote first draft of communication plan for Non-Forest Timber Products. Helped coordinate rollout of PNW Forest Plan Science Synthesis.
- Research Highlights: 105 highlights were reviewed, edited, and will be made available on the web.

- Other High Impact Products: Produced three new glossy handouts: 1) R&D research for NFS; 2) illegal marijuana grows and 3) fire research. Also produced “A Sample of Recent Research Accomplishments: Science and Innovation for a New Century of Conservation.” Informally called “Greatest Hits,” this document--a summary of R&D research achievements—is in production. Large sections of this document were incorporated into a Charles Riley Memorial Foundation document that describes the importance of R&D.
- Altmetrics: Expanded the coverage to track mentions of research outputs as offered on five station websites. Produced 45 weekly reports of “most mentioned” R&D research outputs. Reports were originally used to brief R&D Deputy Chief for weekly meetings with the Chief but were modified to assist public affairs officers in what marketing approach led to improved visibility of Forest Service research results.
- Facebook and Inside the Forest Service: Provide postings for these outlets on a weekly basis.
- Web Modernization: Reached agreement on the design, taxonomy and content types that will, together, define the information architecture and appearance of a common web infrastructure. The new solution will consolidate ten of R&D’s websites into a modern searchable solution offering hundreds of thousands of pages of rigorous, science-based content all under a common department brand.



The *Natural Inquirer* program creates and distributes re-usable science journals and materials written for K-12 students. In FY 2020, approximately 157,602 of these products were distributed to classrooms, homeschools, and individuals across the country. It is notable that the COVID19 pandemic affected our work during FY 20. All work is done with our non-profit partner, the Cradle of Forestry in America Interpretive Association (DBA FIND Outdoors), and the University of Georgia. <http://naturalinquirer.org>

### Important FY20 program accomplishments

The following products were distributed in FY 20:

- 97,318 scientist and engineer cards
- 724 “America’s First Forest” DVDs
- 78 Social Scientists Packs (Four journals and thirteen cards)
- 142 *Natural Inquirer* Reader Packs (Eight readers and seven cards)
- 7,002 *Natural Inquirer* Readers
- 5,990 *Nature Science Investigator* (NSI)
- 11,619 “Bee” *A Scientist* coloring book
- 4,823 “Bee” *A Fire Scientist* coloring book
- 3,330 Advanced Fire Scientist coloring book
- 174 Spanish *Natural Inquirer* products
- 60,284 *Natural Inquirer* publications

**157,602 GRAND TOTAL for all *Natural Inquirer* products**

### Social Media Presence & *Natural Inquirer* website

- Experienced significantly increased engagement rates in August due to distance learning offerings, back-to-school, and new coloring books: 123% increase in Twitter engagement and 900% increase in Facebook engagement.
- Started a *Natural Inquirer* Instagram account
- 93,463 unique visitors to *Natural Inquirer* website

### New products

- Logjams and Beaver Dams monograph (Topic: carbon storage)
- Caves and Karst *Natural Inquirer* journal
- “Bee” *A Fire Scientist* coloring book
- Advanced Fire Scientist coloring book

*Natural Inquirer* products distributed at the following events (Please note this list only captures some of the events where NI materials are distributed, and due to COVID19 many events were cancelled.)

- Project Learning Tree/Project Wild training
- Forest Service Conservation Education Halloween event
- Georgia STEM Forum
- National Science Teachers Association National Conference
- Cradle of Forestry in America (CFAIA) visitor sites & campgrounds
- CFAIA Pisgah Explorers Club
- NAAEE conference
- Kent State University
- Forestry Institute for Teachers (FIT)
- 4-H Arkansas
- *Rensselaer Polytechnic Institute* spring career fair
- Davidson River Campground, Pisgah National Forest
- NYC Watershed Ag Council, Forestry
- Tennessee State University 4-H

### **Partnerships**

- Forest Service Conservation Education
- 4-H (Forest and Agriculture monograph series)
- Forest Service National Symbols program (Woodsy Owl)
- Forest Service International Institute of Tropical Forestry
- National Agroforestry Center

## **National Agroforestry Center**

Established in the 1990 Farm Bill, the National Agroforestry Center advances the health, diversity, and productivity of working lands, waters, and communities through agroforestry. The Center provides science-based information for integrating trees and agriculture on farms, forests, and ranchlands across the United States, to improve water quality, enhance crop and livestock production, create wildlife habitat, and sequester carbon. Located in Lincoln, Nebraska, the Center works with a national network of more than 4,000 natural resource and agriculture professionals who, in turn, provide technical assistance to farmers and landowners.

Work at the Center includes research and/or outreach on the five agroforestry systems most utilized in the United States:

1. Windbreaks and shelterbelts, to shelter crops, people, animals, buildings, and soil from wind, snow, dust, and odors;
2. Riparian forest buffers that filter farm runoff, reduce soil erosion, and diversify income sources;
3. Silvopasture, to increase the efficiency of grazing, pasture and forest land uses, and to diversify incomes;
4. 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
5. Forest farming, or multi-story cropping, to produce food, herbal, botanical, or decorative crops under the protection of a managed forest canopy.

Efforts in FY 2020 included expanding outreach and information transfer through support for partner organizations to develop regionally-specific educational materials on agroforestry practices. Topics funded this year include forest farming in Appalachia, agroforestry in the Midwest, and silvopasture in California. The Center also funded projects to develop outreach materials related to urban agroforestry in Texas, Hawaii, and Washington D.C. In addition, new publications have been produced on land access for agroforestry, soil health, and other agroforestry topics. Research advances have included publishing and presenting research from a systematic review on pollinators in agroforestry systems, continued development of inventorying trees outside forests (TOFs) using high-resolution land cover images, and setting the stage for future agroforestry assessments through a national survey of agroforestry adopters.



## Northern Research Station

The Northern Research Station provides the science land managers, city planners, and policy makers need to improve the condition of the Nation's forests and grasslands. In a region extending from Maine to Minnesota and from Missouri to Maryland, Northern Research Station science aims to understand all the elements of forests and related landscapes. The Northern Research Station is one of seven Forest Service research units conducting research within all 50 states as well as in U.S. territories and commonwealths.

Northern Research Station scientists reach these audiences in a variety of ways, including:

Participation in and contribution to hundreds of consultations with national forest and state forest managers and other partners in efforts to improve access to and use of Station science.

Publishing in peer-reviewed journals and Station technical reports; providing access to over 15,000 publications authored or co-authored by current or former Northern Research Station scientists.

The Station develops [web-based tools](#) that deliver sound, peer-reviewed science in a format that is convenient for land managers and others.

The Northern Research Station's Forest Inventory and Analysis group is responsible for inventory and monitoring in 24 states. The Forest Inventory Data Mart and other tools deliver extensive data, providing stakeholders in State agencies, private industry, and other Federal agencies alternatives for generating tables and maps.

The Station manages 22 of the 81 [experimental forests](#) that are part of the FS Experimental Forest Network; most of these long-term research sites lie within national forests. The ability to conduct scientific research in-house, to apply research findings on National Forest System lands, and to transfer these findings to others for use on all the Nation's forest land sets the Forest Service apart as a natural resource agency.

### NRS Science Delivery Scenarios for compound disasters: COVID-19 and wildfire management

Simultaneously combatting the wildfire-like spread of COVID-19 and actual wildfire is an unprecedented challenge for wildfire management agencies, with impacts on nearly all aspects of firefighting, from training new fire crews to evacuating residents from fire zones. At the request of the Enterprise Risk Management Response Team established by the Executive Leadership Team of the USDA Forest Service to look at this issue, the Strategic Foresight Group at the Northern Research Station rapidly developed scenarios to inform wildfire planning and decision making. Scientists interviewed firefighting and strategic foresight experts and framed four scenarios: "Necessary redirection" (high COVID-19 risk, low fire risk), "Compound disasters" (risk from COVID-19 and fire are both high), "Enlightenment" where both risks are low, and "Normal interrupted" with lower COVID-19 but high fire risks. The "Compound disasters" scenario already had decision makers' attention. But "Normal interrupted" highlighted the possibility of complacency regarding COVID-19 risks. "Enlightenment" captured experts' hopes that a silver lining might be found but would represent a fundamental change in the approach to fighting wildfire, allowing more acres to burn.

### Potential to increase carbon sequestration with tree planting

A Northern Research Station scientist led the most in-depth study to date on how increasing the number of forest trees might offset carbon emissions in the United States. To mitigate tree loss and offset carbon emissions, several initiatives are under way to increase tree planting in forests and landscapes that are not technically defined as forests, such as urban forests. To determine carbon emissions offset from approximately 1.38 trillion trees currently growing in the conterminous United States, researchers examined publicly available data from more than 130,000 forested plots from the national forest inventory conducted by the Forest Inventory and Analysis Program. Forests and harvested wood products annually offset the equivalent of more than 14 percent of economy-wide carbon dioxide emissions in the Nation, however, almost 33 million hectares of productive forest land are understocked with trees. Fully stocking all

understocked productive forest land with trees could increase carbon sequestration by approximately 20 percent. These findings suggest that concentrating tree planting on understocked productive forest land may substantially increase carbon sequestration capacity in the United States.

### **New guidance on long-term urban tree monitoring**

Understanding how an urban forest changes over time, such as mortality and survival rates, how quickly trees are growing, and whether plantings outweigh mortality, requires longitudinal data to track individual trees over many years. Forest Service scientists and colleagues provide methods and strategies for urban tree monitoring in two new guides, adapting well-established practices from forest ecology. These guides are intended for arborists, nonprofit urban foresters, landscape planners, and others who manage trees in cities, towns, and suburbs. Tracking change over time in urban forests enables practitioners to understand mortality and survival rates, growth rates, and changes in tree health and population size. The Field Guide offers detailed protocols for long-term data collection, such as tree location, mortality status, crown vigor, and diameter at breast height. A companion Resource Guide offers strategies for designing and implementing effective monitoring projects, including managing field crews and constructing longitudinal databases. The guides were developed collaboratively with urban forestry professionals, representing the co-production of knowledge across research and practice.

### **New guidelines help cities manage the slow-moving wildfire that is the Emerald Ash Borer invasion**

Emerald ash borer (EAB) is like a slow-moving wildfire spreading through urban forests and killing ash trees. City foresters need guidelines that can slow the insect's spread and preserve a community's investment in urban forestry. To meet city foresters' need for practical management guidelines, Northern Research Station scientists developed a model that evaluates EAB surveillance and control strategies with the objective of maximizing the benefits of healthy trees. The model captures the dynamics of ash trees moving through different levels of infestation. Scientists calibrated and validated the model using 7 years of infestation observations in plots in northern Ohio and subsequently used it to develop the following management guidelines for the city of Burnsville, MN: 1) It is critical to apply surveillance immediately to find the infestation and then treat trees with low to moderate levels of infestation and remove highly infested trees; 2) Surveillance and treatment or removal actions should mainly focus on locations where the infestation has started; and 3) If the budget is not sufficient, the planner may need to forego removing highly infested trees in favor of treating low- and mid-level infested trees to save them and prevent new infestations. These guidelines emphasize the importance of surveillance before treatment or removal to maximize benefits from ash trees and reduce management costs.

### **Synthesis of invasive species research for the U.S. forestry sector**

Invasive species are among the most serious threats to native ecosystems. The introduction and establishment of invasive species continues to increase with ever-expanding world trade, and there appears to be no sign of saturation for most taxonomic groups. Over 100 national experts, including 75 Forest Service experts, contributed to synthesizing the latest research on a wide range of natural science and social science fields that explore the ecology, impacts, and practical tools for managing invasive species. Northern Research Station scientists worked with a planning team of seven scientists from other research stations and the Washington Office to help lead a national stakeholder workshop that included experts on a wide range of topics related to invasive species. Stakeholders from nongovernment organizations, academic institutions, professional organizations, private corporations, and state and federal agencies representing public, private, and tribal interests provided input. The report covers species of all taxonomic groups from insects and pathogens, to plants, vertebrates, and aquatic organisms that impact a diversity of habitats in forests, rangelands, and grasslands of the United States. The report presents the latest research on a wide range of natural science and social science fields that explore the ecology, impacts, and practical tools for invasive species management and provides summaries of the most important invasive species and issues impacting all regions of the country. This comprehensive review will be a valuable resource for scholars, policy makers, and natural resource managers and practitioners.

### **Spatially targeted drone carries biocontrol weevil to hard-to-reach patches of mile-a-minute weed**

A tiny weevil (*Rhinoncomimus latipes*) is a specialist biocontrol agent of mile-a-minute weed, a highly invasive annual plant in the United States. Currently this weevil is released by hand where the presence of the weed is readily detected, which is not practical for large infestations and hard-to-reach areas. West Virginia University researchers and a Northern Research Station scientist developed a spatially targeted biocontrol strategy using an unmanned aerial system, or drone, to detect mile-a-minute weed patches and release the weevil. The team determined the detectability of mile-a-minute weed patches by flying a rotary-wing drone at 15 different altitudes and taking aerial images using natural-color and near infrared sensors. A followup ground survey confirmed the accuracy of aerial images in locating mile-a-minute weed. The team addressed the second problem, weevil delivery, by developing a new insect-release system that uses 3-D printing to create biodegradable polyvinyl alcohol pods. Results showed that mile-a-minute weed patches were readily detectable on the aerial images at an altitude of approximately 25 meters, and more than 98 percent of weevils successfully escaped from the pods within 24 hours after aerial release. Researchers delivered an aerial detection and deployment method that is reliable and environmentally friendly.

### **New and improved site index curves developed for Red Spruce**

One key factor in restoring red spruce is understanding the site quality of potential restoration sites. To assess site quality, foresters measure tree heights and tree ages to produce site index curves for tree species commonly occurring in the area.

Northern Research Station scientists and partners from West Virginia University have developed new site index curves to replace nearly century-old curves to better assess site quality of red spruce habitat. By combining these new site index curves with site specific tree species, climate, and geographic data, the scientists have further refined the estimation of site quality to guide restoration efforts for this important species. With these new site index curves, forest managers can also better estimate growth and yield for future timber production of red spruce. High elevation red spruce in the central Appalachians was historically an important and dominant timber species but is currently reduced to a fraction of its former range due to excessive logging in the late 1800s and early 1900s.

### **A tree species' evolutionary history predicts impact of invasive pests**

Research by Northern Research Station scientists and their partners presented the first evidence supporting a long-held hypothesis that a tree's evolutionary history is key to its susceptibility to nonnative herbivorous insects. Advancing managers' ability to predict which native trees are most susceptible to which nonnative insects has the potential to be a game-changer in managing risk from invasive species.

For more than a century, scientists have worked with little success to understand why some nonnative insects prove devastating and others harmless. In a study of invasive insects affecting conifer species, a research team that includes scientists from the USDA Forest Service, the U.S. Geological Survey, industry, and universities has turned the problem around by considering the insects' host tree species and how they have evolved rather than focusing solely on the insect. The result is a novel model for assessing the probability that nonnative insects that have not yet arrived in North America will cause widespread mortality of North American conifer species. The study revealed that when host trees in an insect's native range are very closely related or very distantly related to its host trees in the invaded range, there is a low probability of impact. However, when the relatedness of hosts in the native and introduced ranges are intermediate, there is a much higher probability of tree damage and death at the ecosystem scale.

### **A new model forecasts Emerald Ash Borer invasion across the nation**

From the time that emerald ash borer was first detected near Detroit, MI, nearly 30 years ago, homeowners and communities have had little warning of where and when the insect would spread. A new model developed by a Northern Research Station scientist and his collaborators forecasts emerald ash borer invasion from 2022-2030, creating a critical new tool in protecting ash forests in rural and urban landscapes. Since its accidental introduction to the United States, the emerald ash borer has virtually "burned" across the country, leaving a path of dead trees throughout more than 600 counties as it continues to spread. The loss of ash trees has had economic, social, and ecological impacts for forest managers, homeowners, municipalities, and many others. Predictions of when emerald ash borer is likely to invade new regions would be of critical value for communities in their preparations and response to the invasion. A Northern Research Station scientist and his partners used historical records of emerald ash borer invasion in the United States to fit a mathematical model of this spread from 2022 to 2030. The model is based on statistical analyses linking historical spread of the insect with human population densities, climate, and forest composition. Simulations using this model indicate that the insect will continue to invade new regions of the United States including those contiguous to currently invaded areas, but also more distant locations, such as major population centers of the American West.

### **New adaptive tools enhance shared stewardship in battling Asian longhorned beetle**

Researchers and managers with the USDA Forest Service and Animal & Plant Health Inspection Service (APHIS) are developing new tools that share the activities and results of the cooperative Asian longhorned beetle (ALB) eradication programs, contributing to a more efficient response and speedier eradication of a potentially devastating nonnative invasive species. The ALB is an invasive insect that threatens some of the most iconic trees in eastern North America, including maples, willows, and poplars. Eradication programs depend on visually surveying individual trees to find infested hosts. In wooded landscapes this can mean surveying millions of individual trees, and multiple surveys may be required to achieve eradication. In 2020, a computer software tool called the "ALB Dynamic Risk v1.0" was expanded to integrate not only the dispersal of the insect, but the history, frequency, timing of surveys, and population growth rates to generate dynamic estimates of risk on the landscape. This tool delivers a consistent method to track the reduction in risk on the landscape as eradication programs progress and to identify parts of the landscape where surveys can provide the greatest progress toward eradication. It also can be adapted as new information becomes available.

### **Training program becomes foundation of collaborative oak regeneration crusade**

In mixed-oak landscapes, regenerating oak is something of a holy grail. An oak regeneration decision-support system developed by Northern Research Station scientists and partners is becoming a foundational tool in efforts to sustain oak forests in Ohio. Developed and sustained by Northern Research Station scientists, SILVAH (Silviculture of Allegheny Hardwoods) is a decision-support system that applies research results to prescribed treatments that improve regeneration outcomes for mixed-oak and Allegheny hardwood forests. Since 2009, 6-week-long SILVAH Oak training workshops have been held at the Vinton Furnace Experimental Forest in Ohio and attended by more than 200 land managers from federal and state agencies, as well as private consulting foresters. The intensive training includes lectures on oak ecology and silviculture, field tours to demonstrate silviculture practices, collection of SILVAH plot data in the field, and an introduction to the software. Three Northern Research Station scientists led the most recent workshop conducted in fall 2019. The SILVAH system is being used by the Wayne National Forest and the Ohio Department of Natural Resources, Divisions of Forestry and Wildlife, in their efforts to sustain oak forests.

### **Videos make forest management strategies engaging and understandable for landowners**

Scientists have conducted research on sustainable forest management at the Penobscot Experimental Forest in Maine for 70 years, generating reams of journal articles and reports that would help a landowner decide whether (and how) to manage their woodlands. Their findings highlight the advantages and disadvantages of different approaches to harvesting, including treatments that maintain forests with simple versus complex structures, few versus many tree species, habitat for early versus late successional species, and maximum short-term versus sustained long-term income. This information is important for landowners of small tracts who are uncertain whether or how they should manage their woodlands, but the types of reports scientists write can be difficult to access and understand. To bridge the divide between experts and non-experts, the USDA Forest Service partnered with the University of Maine, Maine Audubon, and New England Forestry Foundation to produce two videos highlighting research results and introducing concepts of sustainable forestry. These videos include historical and contemporary images from different types of management on the Penobscot Experimental Forest showing how the forest changes over time, as well as interviews with landowners, foresters, and scientists in Maine. Managing for wildlife, carbon, aesthetics, and timber are discussed and common pitfalls and concerns are explained. More than 4,000 people watched the videos in the first few months they were available online. A companion publication is in development.

### **Rooted in Research**

In 2020, the Northern Research Station launched a new bimonthly publication that synthesizes key science findings and management implications of research conducted by Northern Research Station scientists and collaborators. Rooted in Research is targeted to public land managers in our overall foot print and other individuals who make and influence decisions on managing land. This new publication is designed to bring current research to the most pressing natural resource management issues through succinct, comprehensible science stories, while rewarding station scientists by providing them with a straightforward medium for science delivery. The first two issues described science related to white-tail deer, a perennial obstacle to forest regeneration throughout the Northern Research Station's footprint, and research on adapting red pine forests to changing habitat conditions. The publication will be distributed via Constant Contact, making it a highly accessible source of regional forest science.



### **Pacific Northwest Research Station**

The Pacific Northwest (PNW) Research Station develops and delivers knowledge and innovative technology to improve the health and use of the Nation's forests and rangelands—both public and private. Since 1925, the PNW Research Station has been dedicated to understanding forests and rangelands. We believe that resilient forests are a promise to generations to come—a promise to replenish the air we breathe and the water we drink and use to grow food. Forest trees store carbon from the roots to the tops. Trees supply wood for homes, biomass for fuel, and fiber for paper. From remote mountains to bustling cities, forests provide habitat for fish and wildlife. Wherever they grow, forests are places of beauty, renewal, and solace.

Land managers understand more than ever just how important forests are to people from every walk of life. The PNW Research Station is in the unique position to offer scientific knowledge—built on decades of research—that can be used now to assure future generations enjoy the same benefits from forests that we do today. As part of Research & Development, the station has access to national forests and an experimental forest system that hold the keys to new understanding of forests and rangelands.

The PNW Research Station has strong partnerships with universities, national forests, state agencies, nonprofits, private industry, and other federal agencies. With these partners, we address key questions associated with managing forests, wildlife and fish habitat, recreation, climate change, human health and well-being, and more. We have the honor of bringing science to the table as people make often-difficult choices about managing land.

The PNW Research Station is a leader in the scientific study of natural resources. We generate and communicate impartial knowledge to help people understand and make informed choices about natural resource management and sustainability.

## Research in progress

### West-side fire research initiative

The PNW Research Station launched the [West-Side Fire Research Initiative](#) in 2019 to produce information relevant to fire-related management on landscapes west of the Cascade Range in Oregon and Washington. Wildfires on the west side of the Cascades are becoming more frequent and more intense, with increasing risk to the extensive wildland-urban interface in the area. Scientists, fire managers, and other stakeholders are working to coproduce the science needed to keep people safe and the forests resilient. The group identified 3 priority areas for research: 1) historical and future fire regimes; 2) fuel management; and 3) postfire management. The West-Side Fire Research Initiative will produce actionable science and tools that help managers and responders plan for changing fire regimes on the west side of the Cascades.

### Carbon dynamics research for land and watershed managers

In 2019, the PNW Station launched a [carbon research initiative](#) to enhance policy-relevant understanding of carbon flux and carbon accounting, and to fill knowledge gaps about forest carbon dynamics. Forest carbon accounting is notoriously complicated, and uncertainty over the state of science hinders forest management.

The research initiative is addressing unresolved questions of policymakers and other partners. Working groups consisting of researchers, policymakers, and natural resource managers have convened around three questions:

- How do we identify and improve the most appropriate carbon models of the forest sector and all lands?
- What is the state of the current knowledge for green carbon in Pacific States?
- What are the carbon fluxes and social implications of different forest management strategies?

This initiative will deliver tools and information to policymakers and other partners that will help answer questions about forest carbon and how it interacts with other forest management objectives and practices.

## PNW Science Delivery

### New tool supports informed decisions about the combined effects of wildfire smoke and COVID-19

Degraded air quality from wildfire smoke may exacerbate the respiratory effects of COVID-19, potentially increasing infection rates and worsening infection outcomes. To mitigate the health impacts from the confluence of smoke and COVID-19, researchers with the PNW Research Station, USFS Interagency Wildland Fire Air Quality Research Program, and USFS Fire and Aviation Management created a national Smoke-COVID dashboard to help agency personnel make decisions in situations where both smoke and COVID-19 are factors. The tool tracks and integrates data on COVID-19 cases alongside air quality monitors, fire incidents, satellite fire and smoke detections, and smoke forecasts on a novel platform.

### AirNow.gov map makes air quality data available to the public for the first time

Wildfire smoke is the predominant cause of major air quality events in the United States that affect millions of Americans each year, causing significant negative health effects. To enhance the current air quality monitoring system across the country, researchers from the USDA Forest Service and the Environmental Protection Agency supplemented existing monitoring systems with data from low-cost sensors, dramatically expanding the spatial coverage of air quality monitoring systems the United States.

### Integrated climate and genetic monitoring of invasive forest pathogens helps Hawaii protect native trees

Climate change is predicted to exacerbate invasions by forest pathogens and predispose trees to emerging diseases, fire, insects, and other disturbances. Scientists used bioclimatic models to predict current and/or future distribution of brown root rot (*Phellinus noxius*) and myrtle rust (*Austropuccinia psidii*). They verified several genetic groups within both invasive species, and bioclimatic modeling showed that distinct genetic groups pose distinct threats, which must be recognized by regulatory agencies to limit damage and mortality to trees in the tropics and subtropics from these invasive pathogens.

### SoCal EcoServe: A tool for visualizing and quantifying impacts of fire on ecosystem services in southern California

The tool quantifies and maps pre- and postfire ecosystem services for the shrubland-dominated national forests in southern California. It compiles modeled spatial data relating to water supply and flood control (hydrological runoff, groundwater recharge, and sediment export), carbon storage, biodiversity and recreation. It provides a repeatable and transparent framework for quantifying the change in ecosystem services and their values associated with damage to natural resources on national forest lands.

### Retaining logging debris on site yields multi-year benefits for replanted Douglas-fir

Scotch broom, a nonnative shrub, invades sites following timber harvests in coastal regions of the Pacific Northwest. It outcompetes native vegetation for water and nutrients. Results from a long-term soil productivity study in western Washington indicate that the benefits of retaining logging debris on site can be measured up to 15 years later in the survival and growth of Douglas-fir planted after the previous harvest.

### **Informing habitat restoration for Coho salmon**

Oregon coastal Coho salmon (*Oncorhynchus kisutch*) are listed as threatened under the Endangered Species Act. Forest Service research revealed the importance of connectivity among different types of freshwater habitat for Coho salmon (adult spawning habitat; juvenile summer rearing habitat; juvenile winter refuge habitat). Restoration projects that only focus on individual habitat segments may not lead to watershed-scale improvements. Targeted restoration that fills habitat gaps may be more effective when diversity, location, and proximity of seasonally important habitats already present in a watershed are considered.

### **Fish density tells the story: large-river stream restoration works**

In the Pacific Northwest, millions of dollars have been spent on stream habitat restoration projects designed to improve rearing conditions for Pacific salmon. New research provides rigorous methods to more conclusively identify fish response to these projects. When applied to the Entiat River system in Washington, the methods show that restoration projects increase the capacity of the river or stream to support fish. This finding has provided sponsors of restoration projects in the Entiat River system with increased confidence in the success of their efforts.

### **A new mobile app for collecting stream data essential for management**

The western Oregon stream [FLOW PERmanence](#) (FLOWPER) project is using the latest technology to more accurately characterize headwater streams in western Oregon as seasonal or year-round flows. The presence of year-round water determines the size of riparian buffers that are required by the Northwest Forest Plan, the Oregon Forest Practices Act, and best management practices. This project will help reduce the cost of pre-project planning and monitoring associated with forest management activities.

The FLOWPER project is yielding field data and lidar data that are being used to update the National Hydrographic Dataset, the centralized, multi-agency, stream dataset that forms the foundation for land management with respect to streams. The long-term goal is for FLOWPER to become a nation-wide, multi-agency resource to help inform land management on all federal lands.

### **Controlling pest outbreaks to enhance the health of western forests**

Scientists and national forest managers collaborated on a study to abate outbreaks of the Douglas-fir tussock moth. In the Okanogan-Wenatchee National Forest, the model predictions were directly used to allocate biocontrol efforts to manage moth outbreaks at several sites on the forest. The results largely followed predictions, thus showing the benefit of these models in pest management.

### **Passive acoustic monitoring effectively detects northern spotted owls and barred owls**

Northern spotted owls (*Strix occidentalis caurina*) are listed as threatened under the Endangered Species Act. Populations have been monitored since the mid-1980s by using labor intensive mark-recapture methods that require call-back surveys and using mice to lure owls for capture and leg-band reading. Land managers, conservationists, and researchers have sought alternative methods that yield robust data while being less costly, suitable for multiple species, safer for field crews, and noninvasive for spotted owls.

The results of study that used passive bioacoustics as an alternative survey method demonstrate that it can effectively meet monitoring objectives. These findings are being used to design and inform the transition from mark-recapture to passive bioacoustics as the primary monitoring method for northern spotted owl populations under the Northwest Forest Plan effectiveness monitoring program.

### **Effects of common management practices on greater Sage-grouse synthesized for easy reference**

This new resource describes specific characteristics of suitable habitats for greater sage-grouse, a bird that been proposed for listing under the Endangered Species Act and is ranked as imperiled in several western states. The authors summarized the published literature on predominant management activities, including fire, grazing, pesticide and herbicide application, and energy and urban development. The resource also includes a unique comprehensive tabulation of vegetation structure and composition in sage-grouse breeding habitats, summarized by management practice and habitat type, for all states and provinces in the species' range. The new synthesis was downloaded more than 150 times in the first months of its release.

### **Higher sales prices for single-family homes associated with urban trees in Tampa, Florida**

The City of Tampa faces major redevelopment pressure that could directly affect the relationship between urban trees and single-family house prices. Policymakers and developers wanted to know how the presence of trees could affect the value of houses being sold for redevelopment.

Researchers found that, after accounting for the influence of different house and neighborhood characteristics, houses with trees within 500 feet of the lot were associated with higher sales prices. A 1-percent increase in tree cover was associated with an increase in sales price of more than \$9,000. The City of Tampa used this information to inform revisions to their tree protection ordinance.



## Pacific Southwest Research Station

The Pacific Southwest (PSW) Research Station represents FS R&D in the states of California and Hawaii and the U.S.-affiliated Pacific Islands. The region has the lowest, driest desert in the country, the highest elevations within the 48 contiguous States, and the wettest tropical forests. It is home to an abundant diversity of native plants and animals and nearly half of the Nation's threatened and endangered species. PSW scientists are engaged in research across a network of 14 experimental watersheds, ranges and forests and eight research facilities. PSW scientists conduct a broad array of natural resources research to achieve our mission to "develop and communicate science needed to sustain forest ecosystems and their benefits to society." Research is organized into five research units: conservation of biodiversity, ecosystem function and health, fire and fuels, urban ecosystems and social dynamics, as well as Pacific Islands forestry. For more information, visit [www.fs.fed.us/psw](http://www.fs.fed.us/psw).

### PSW Science Delivery

#### Plant pathology program

PSW scientists, working with state and university partners, developed a plant pathology program at its Institute of Pacific Islands Forestry (IPIF) to coordinate and implement all aspects of a complex major forest pathogen including detection, evaluation, prevention, resistance, and control programs for such diseases as Rapid 'Ōhi'a Death ) This program will create a well-organized science-based system for identifying and addressing new pathogens. Hawaii's climate and role in the importing and exporting of products makes it especially susceptible to harmful forest pathogens. Having a well-organized system in place will minimize the negative ecological impacts and costs that these pathogens can cause.

#### Field monitoring of urban trees

Field monitoring of urban trees is essential to understanding how urban forests change over time. Two companion reports – the *Urban Tree Monitoring: A Field Guide* and the *Urban Tree Monitoring: A Resource Guide* -- lay the foundation for practitioner-driven long-term studies of tree mortality, growth, and health. The Field Guide gives detailed protocols for how to record a key set of variables, including mortality status, location, trunk diameter measurements, and crown vigor. The resource guide offers a lengthier deep-dive into various considerations for designing and implementing a monitoring program. In addition, five short films, produced in collaboration with Forest Service's Pacific Southwest Region, explain select parts of the field guide and resource guide and, like the guides, are intended for urban forestry professionals such as those working for municipalities, state forestry agencies, local urban greening nonprofit organizations, urban forestry advocacy groups, and contract urban foresters.

#### Stanislaus National Forest scenario planning project

PSW scientists are working closely with Stanislaus National Forest staff, local collaboratives, and with Alan Ager and his (ForSysX) team on one of only a few serious pilot efforts nationwide to examine use of ForSysX on a specific national forest. The team has identified the 5 objectives that are most important for the local planning area, have set up a team specific to each objective, and have developed a list of data needs to inform the planning around each objective. While there is much work yet to be done, the work completed in FY 20 has been foundational the success of this scientifically informed scenario planning strategy.

#### A framework for socio-ecological resilience in the Sierra Nevada

A collaborative of 10 agencies and organizations, the Tahoe Central Sierra Initiative (TCSI), is working to improve landscape resilience in the central Sierra Nevada through a strong scientific foundation, innovation, and action. As part of the scientific foundation, a Framework for Socio-ecological Resilience was recently completed. In the 2.4M acre TCSI landscape, we are demonstrating how the Framework can be used to identify opportunities where future management can be directed to move toward desired conditions across the landscape. The Framework for Resilience and its application in the TCSI landscape provide a valuable model for how assessments and planning across large, regional-scale landscapes can directly inform and support project planning.

## Lake Tahoe restoration

Science supports progress: Over the past 4 years in the Lake Tahoe basin, PSW scientists have been leading a science team, working shoulder-to-shoulder with NFS staff and colleagues from various universities to address a fundamental question facing most landscapes, which is “how much of what type of treatments will be most effective in achieving multiple restoration objectives.” The diverse interdisciplinary science team had expertise in forestry, fire, wildlife, smoke, hydrology, and economics. We developed a novel approach to evaluating the performance of five different management scenarios and climate change modeled over nearly 100 years across the 60,000 acre landscape on the west shore of Lake Tahoe that addressed how management could be designed and implemented to accomplish objectives in all six resource areas. The results were used to inform a Landscape Restoration Strategy for the Lake Tahoe west landscape, as well as provide a foundation for developing basin-wide management strategies that can help forest ecosystems adapt to future climate conditions and retain high environmental quality in the watersheds of Lake Tahoe.

## Variable density thinning

PSW scientists published work detailing initial results of a study finding that, when followed up with prescribed fire to reduce surface fuel loads, stands treated with “high variability” thinning should not only provide greater habitat value to associated animals and plants, but also enhance resilience to drought and wildfire. Many land managers, including the managers from the Stanislaus National Forest where the studies have taken place, eagerly anticipate the additional research on this topic for use in their NEPA analysis and project implementation.

## Detecting illegal marijuana grow sites

The USFS initiated a program using new high-tech and non-traditional technologies to gain an upper hand on detecting even well-hidden grows. Forest Service R&D partnered with law enforcement and Integral Ecology Research Center (IERC) to develop the Detection and Interdiction of Marijuana to aid Enforcement and Conservation (DIMEC) model to identify grow sites hidden in the forest canopy using deep learning image recognition of high-resolution aerial imagery. The tool can identify grows outside of the growing season allowing for more cost effective and safe remediation of sites before the growers return in the spring.

## 3rd experimental timber harvest

A long-term partnership between the Pacific Southwest Research Station and the California Department of Forestry and Fire Protection led to the successful implementation of the 3rd experimental timber harvest in the Caspar Creek Experimental Watersheds. The first two experiments at Caspar Creek led to substantial changes in sustainable forest management within the state of California, as well as foundational understanding of forest hydrology and watershed responses to disturbances. With its extensive and intensive scope and its encompassing collaborative approach, the 3rd experiment is positioned to build on the legacy of foundational and applied forest hydrologic research and expand our knowledge about the impacts of forest management for decades to come.



## Rocky Mountain Research Station

Rocky Mountain Research Station scientists work in a range of biological, physical and social science fields to promote sustainable management of the Nation's diverse forests and rangelands. The Station develops and delivers scientific knowledge and innovative technologies with a focus on informing policy and land-management decisions. Our researchers work in collaboration with a range of partners, including other agencies, academia, nonprofit groups, and industry. The Rocky Mountain Research Station serves the Forest Service as well as other federal and state agencies, international organizations, Tribes, academia, non-profit groups and the public. Our Science Programs include: [Air, Water and Aquatic Environments](#); the [Aldo Leopold Wilderness Research Institute](#); [Fire, Fuel and Smoke](#); [Forest and Woodland Ecosystems](#); [Grassland, Shrubland and Desert Ecosystems](#); [Human Dimensions](#); [Inventory and Monitoring](#); [Science Application and Communication](#) and [Wildlife and Terrestrial Ecosystems](#).

RMRS maintains 14 research laboratories throughout a 12-state territory encompassing the Great Basin, Southwest, Rocky Mountains, and parts of the Great Plains. RMRS administers and conducts ecological research on 14 [experimental forests, ranges and watersheds](#) over the long-term. Some of this research dates back over a century and offers invaluable insight into how forests change over time, particularly as we face a changing climate and new disturbance regimes. We also oversee activities on several hundred [research natural areas](#), a network of ecosystems set aside to conserve biological diversity.

The Rocky Mountain Research Station public-facing website uses a modern Drupal-based platform which has provided a template for modernization for Research & Development. This year our website had over 900,000 pageviews (a 20% increase from last FY). The Rocky Mountain Research Station is actively engaged in the R&D web modernization effort, which will greatly improve efficiency of IT resources, unify R&D, and allow R&D web content to align with USDA web requirements.

The Rocky Mountain Research Station [Science You Can Use](#) (SYCU) publication continues to be highly regarded and sought after by land managers, congressional staff and other scientists. This year we continued to expand our reach and impact. We produced 6 SYCU *Bulletins* and 17 SYCU *(in 5 minutes)*. We also launched a highly successful *Science You Can Use* webinar series in the spring to take advantage of the maximized telework stance. These short, interactive land manager-focused webinars enjoyed excellent participation (1,400 attendees at live webinars, 5,351 follow-up webinar pageviews). We also created and shared monthly growing season rangeland fuels webcasts, which were particularly timely given intense drought conditions in southwest rangelands.

## RMRS teaches at NAFRI

Several Rocky Mountain Research Station scientists taught lessons in two separate weeklong trainings at the National Advanced Fire and Resource Institute (NAFRI) in Tucson, Arizona in January 2020. Both courses use lectures, case studies, a field trip, and structured interaction among and between students and faculty to deliver science and create a



The Science You Can Use publications synthesize research conducted by station scientists and collaborators and deliver key science findings and management implications to people who make and influence decisions about managing land and natural resources.

shared learning experience. The first class, Advanced Fire Effects, also known as RX510, supports the integration of fire effects knowledge into land management programs. This course, for wildfire operations personnel and fire practitioners, emphasizes design, implementation, and monitoring of planned fire treatments over space and time. The second class, Fire in Ecosystem Management, or M580, enhances the knowledge and understanding of fire management and fire ecology. This course targets resource managers, wildland fire planning personnel, and line officers to become actively engaged in ecosystem management across the landscape. RMRS scientists with the National Fire Decision Support Center taught students about Fire Economics and Ecosystem Services. Faculty cadres for both training courses included scientists and managers from several universities and other federal and state agencies. NAFRI is a national training center dedicated to the diverse interagency fire, fuels, resource, and incident management community in developing and enhancing learning experiences. The Institute assists in the creation of innovative solutions that concern fire and all-hazards management. You can find more information on NAFRI and their available courses on their website.

### *Integrating more social science into public engagement and National Forest planning processes*

Social science recently developed at the Aldo Leopold Wilderness Research Institute, in collaboration with the University of Montana, has focused on providing the National Forest planning community with scientifically robust tools for integrating diverse values and perspectives into the planning process. These tools, such as the recently published social vulnerability protocol (<https://www.fs.usda.gov/treearch/pubs/59038>), have been communicated to federal land managers and planners through a “Science You Can Use” webinar. In addition, Aldo Leopold Wilderness Research Institute scientist Chris Armatas recently presented, as an invited guest, to The Wilderness Society about social science methods for application in broad-scale planning processes. While the federal land management agencies generally lead the planning process and the corresponding public engagement, participation of non-federal entities (e.g., NGOs, interested citizens) is critical to successful planning efforts (e.g., forest plan revision, comprehensive river management planning). As the Forest Service continues to pursue shared stewardship, communication between the agencies and non-agency stakeholders will be critical. Social science can help such communication.



RMRS scientist Chris Armatas works with National Forest System collaborators at Forest Plan Revision meeting.

### **Wildfire risk to communities**

Wildfire Risk to Communities is a joint partnership effort between USDA Forest Service Washington Office Fire and Aviation, Rocky Mountain Research Station Fire Modeling Institute, Pyrologix (a geospatial analysis company headquartered in Missoula, MT), and Headwaters Economics (a research nonprofit based in Bozeman, MT). This program was directed by Congress under the 2018 Omnibus Act to help communities understand, manage, and mitigate wildfire risk. Spatial products are geared towards several groups including elected officials, land use planners, fire collaborative, and fire marshals. Products include maps showing wildfire likelihood, home risk, and wildfire source areas. Maps are available at [www.wildfirerisk.org](http://www.wildfirerisk.org). Additional information about this work can be found here: <https://www.fs.usda.gov/rmrs/science-spotlights/wildfire-risk-communities>

### **WildfireSAFE**

WildfireSAFE is a new app developed by Dr. Matt Jolly of the Rocky Mountain Research Station Fire, Fuels, and Smoke Science Program that is designed to help fire managers understand fire hazards and make informed decisions concerning wildfire incident management and resource prioritization. WildfireSAFE integrates real-time data from multiple data sources, like drought conditions from the U.S. Drought Monitor and satellite-derived vegetation conditions, into a single, user-friendly web platform. Within minutes of a reported wildfire, fire managers can open the app and zoom in on the wildfire's location. They can then view weather analysis for any active incident, compare active incidents within an area of interest, and capture observations about fire behavior. The app also automatically analyzes the fuels, terrain conditions, and values at risk in the surrounding area. WildfireSAFE is available on desktops, tablets, and mobile devices, and is designed to be used by the Forest Service as well as private industry, local and state firefighting organizations, and the general public. The app is already



In the WildfireSAFE desktop and mobile apps, users can navigate to a wildfire and find real-time data that includes seven-day weather fire danger forecasts, terrain, and drought conditions.

in use in the field, supporting the interagency fire community in the planning, response, and recovery phases of wildfire management. More information can be found at <https://wildfiresafe.technosylva.com/> Read more about WildfireSAFE here: <https://www.fs.usda.gov/rmrs/science-spotlights/wildfiresafe-real-time-data-improve-wildfire-management>

### **Lessons Learned after 20+ years of fuel treatments in a ponderosa pine forest**

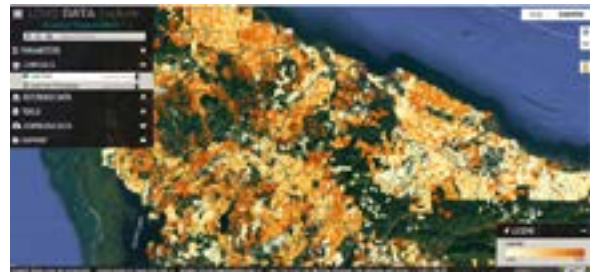
The Lick Creek Demonstration/Research Forest studies were established in 1991 in western Montana to evaluate tradeoffs among alternative forest cutting (i.e., thinning and retention shelterwood) and burning strategies aimed at reducing fuels and moderating forest fire behavior while restoring historical stand structures and species compositions. These types of long-term studies are critical for forest managers across jurisdictions. The experiment consists of two independent studies of thinning and retention shelterwood cuttings, with and without prescribed burning treatments. Throughout the 23 years since the treatments, numerous effects on the forest ecosystem have been studied, including fuels, forest structure and composition, understory species responses, tree physiology, resistance to bark beetles, carbon storage, and fire hazard. Permanent photo points established in each study also visually document forest and fuel change over time. Our findings are actively being shared with land managers via a Joint Fire Science Program brief and an upcoming Science You Can Use. An important finding of this work is that fuel reduction and restoration treatments are most successful with a combination of cutting and burning strategies. However, fuel treatments in low-elevation dry forests will likely not remain effective for much longer than historical mean fire return intervals, so maintenance/re-entry treatments are needed. Read this research spotlight to learn more: <https://www.fs.usda.gov/rmrs/science-spotlights/lick-creek-lessons-learned-after-20-years-fuel-treatments-ponderosa-pine-forest>

### **FIA specialists update REDDcompass forest monitoring tool**

Forest Inventory and Analysis (FIA) specialists from the Rocky Mountain Research Station and the Northern Research Station served as co-authors of the multinational Methods and Guidance Documentation that forms the basis of the newly updated REDDcompass forest monitoring tool. Numerous countries use REDDcompass as a road map for developing national-scale forest monitoring systems that are compliant with guidance issued by the Intergovernmental Panel on Climate Change (IPCC). The updated tool offers expanded guidance on ground data, including national forest inventories, statistical estimation techniques, and integration of ground data with remote sensing. The USDA Forest Service supported the contributions of several current and former FIA specialists via the interagency SilvaCarbon program, which addresses the USDA Forest Service strategic goal of applying knowledge globally. REDDcompass is hosted by the Global Forest Observations Initiative, under the umbrella of the United Nations Food and Agriculture Organization.

### **New landscape change monitoring system**

The [Landscape Change Monitoring System](#) (LCMS) is an important new dataset and tool that allows the user to create landscape-scale historical disturbance maps. LCMS combines satellite imagery with other monitoring data to produce annual maps showing change (vegetation loss and vegetation gain), land cover, and land use, generating a “best-available” map covering multiple disturbance processes and diverse cover types. The data and tool can assist with forest plan revision, updating existing vegetation maps, assessing landscape conditions, supporting post-fire recovery, meeting broad-scale monitoring requirements, and other tasks. Staff can receive [training](#) in using LCMS through the USDA Forest Service Geospatial Technology and Applications Center (GTAC), and the tool and a tutorial are available to the general public through a web-based application. LCMS was shared widely with land managers as a recent [Science You Can Use \(in 5 minutes\)](#).



The Landscape Change Monitoring System helps understand and visualize landscape-level changes over time.

### **New Conversion of FIA data simplifies use in Forest Vegetation Simulator**

Using combined analytical power, a breakthrough in data translation and conversion combines the power of two forestry analysis tools in answering forestry management questions. Together, the Forest Inventory and Analysis (FIA) database and the Forest Vegetation Simulator (FVS) comprise a powerful toolset that allows managers and researchers to assess the status and trends of a wide variety of forest types over large areas. Users can also evaluate the outcomes of possible future management scenarios. The FIA program collects data on forest characteristics in all forest types and across all ownerships in the United States (non-forest locations in many regions are also visited to quantify rates of land use change). The FIA database represents the largest and most diverse forest database in the world.

FVS is a computer program used by a variety of managers and scientists to project today's forest conditions into the future. For almost two decades there has been increasing demand to use FIA data in FVS but translating the data from one format to the other has been a difficult task. Previous translations were either incomplete or contained errors, so the combination of the data and program could not be used to its full potential. John Shaw, a Rocky Mountain Research Station Research Forester and analyst for the FIA Program, has played a key role in developing a new translation process, which converted FIA data from over 1 million plot visits into a format that is read directly by the FVS. This new datamart URL is easily accessible at <https://apps.fs.usda.gov/fia/datamart/datamart.html>

## Synthesis tools for forest planning

A new publication by RMRS scientist Kas Dumroese and his collaborators, called [Northeastern California Plateaus Bioregion Science Synthesis \(RMRS-GTR-409\)](#), is the result of a specific request made by local governments to the Forest Service Pacific Southwest Regional Forester. The synthesis has a Northeastern California focus on sagebrush rangeland, dry pine forestland, juniper forests, habitat and wildlife, society, and response to disturbances, particularly those related to climate. The Lassen and Modoc National Forests are located where the Great Basin, the Sierra Nevada, and the Southern Cascades meet. For forest plan revisions, other science syntheses have focused on the Cascades and the Sierra Nevada and are relevant to the Lassen and Modoc National Forests but do not cover some important ecosystems and topics. The newly published RMRS-GTR-409 resulted from a specific request made to the Pacific Southwest Regional Forester by local governments to cover ecosystems and topics not discussed in the other two syntheses. The scope was the direct result of public involvement, and includes information on dry pine forestland, sagebrush rangeland, habitat and wildlife, society, and response to disturbances, particularly climate. Together, these three syntheses complete the scientific picture that will inform forest plan revisions on the Lassen and Modoc, as well as other National Forests in the Western United States with similar habitats and help meet the 2012 planning rule requirement for using the best available science. Read more about this science in this Science You Can (in 5 minutes) which was shared widely with land managers: [New California Plateaus Science Synthesis: Science Supporting Dry Forest and Rangeland Planning](#).

## Adapting the common garden tool to guide forb seed transfer

Common gardens are a tool for examining variation in performance across the range of a plant species and are the best way to develop seed transfer guidance for restoration. The Great Basin Native Plant Project, a USDA Forest Service- and Bureau of Land Management-led partnership, is developing seed transfer guidance for native forbs, important components of wildlife habitat but underutilized in restoration efforts. We selected three common Great Basin species considered important for management needs. Seedlings from many populations of each species were planted into six common garden sites across Idaho, Nevada, Oregon, and Utah, where their performance in each environment is monitored. Many partners coordinate resource acquisition, land use and garden monitoring, including: The Nature Conservancy, Eastern Nevada Landscape Coalition, University of Nevada Reno, Utah State University, and many USDA Forest Service and Bureau of Land Management resource managers. The end-product will be a spatially explicit restoration tool that will inform the appropriate selection of seed for restoration projects and will be useful for public and private landowners, the seed industry and others interested in restoring range landscapes. Future goals include incorporating additional species and creating a streamlined approach to seed transfer development. For more information, see our [Science Spotlight](#).



This synthesis includes a section on rangeland, covering topics such as public perceptions; interactions of grazing, climate change and carbon storage; rangeland restoration; managing threats to rangeland; and biological soil crusts

## Climate Smart Restoration Tool: planning restoration now and for the future

Decades of genetic research have shown that environment, in particular climate, strongly affects plant fitness and the geographic distance seed can be moved from its collection source. Are local populations genetically positioned to mitigate climate change? If not, where do seeds/seedlings need to be moved to maintain species fitness? The Rocky Mountain Research Station collaborated with the U.S. Department of Agriculture, the Bureau of Land Management, the Pacific Northwest Research Station, Utah Department of Natural Resources and Conservation Biology Institute to develop the [Climate Smart Restoration Tool](#) (CSRT), a web-based platform that maps seed transfer areas, capitalizes on these genetic models, ensemble climate change models and species niche models to map current or future seed transfer areas for individual species. Users simply choose the timeframe (contemporary or future projections), location and species, and the website tool calculates and maps areas suitable for seed transfer. This tool applies to all western states, current species and restoration needs are most applicable to Idaho, Nevada and Utah. Read more about genetic models for [big sagebrush](#) and [bluebunch wheatgrass](#).

## North American nursery technology webinar series

A [Nursery Technology Webinar Series](#) was developed for forest and conservation nurseries throughout Idaho and North America. The series, that was initiated, planned, and led by Rocky Mountain Research Station Research Plant Physiologist Jeremiah Pinto, aims at bringing nursery technology information to managers, end-users, growers, and technicians in the absence of in-person meetings due to the COVID-19 pandemic. Read more about how Rocky Mountain Research Station

scientists support public and private nurseries in [The intersection of science and technology transfer: Reforestation, Nurseries, and Genetic Resources Team](#). Five U.S. and Canadian nursery associations, including one managed by the University of Idaho, are participating. Registrations topped 500 and include participants from around the world.

### **Pinyon and juniper science synthesis**

Pinyon and juniper woodlands occupy over 70,000 square miles of the Great Basin and Colorado Plateau including parts of Idaho, Nevada, Utah, and other western states. Changes occurring in these ecosystems—both expansion and contraction—are of concern to land managers and communities. A new, comprehensive science synthesis provides the best-available information on the distribution, history, ecology, hydrology, and management of these woodlands. The synthesis identifies management strategies to meet local needs and will be of interest to managers, researchers, and the public. Coauthors are from Oregon State University, the Rocky Mountain Research Station, the Bureau of Land Management, and the USDA Agricultural Research Service. Read more in: [The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Northern Colorado Plateau of the western United States](#).



School teachers sow paintbrush and yucca seeds in the new Cultural Plant Propagation Center at the Moencopi Day School in Tuba City, AZ

### **A semiochemical tool for manipulating tamarisk control**

Saltcedar (*Tamarix* spp.), an aggressively invasive Eurasian tree, is a dominant and widespread woody riparian species in the southwestern U.S. While saltcedar's extensive displacement of native trees is detrimental, it is now used as habitat by many species, including the endangered southwestern willow flycatcher (*Empidonax traillii extemus*). The leaf beetle *Diorhabda carinulata* feeds on saltcedar foliage, so it can be used as a control agent to manage saltcedar invasion. This biocontrol can be made more effective with semiochemicals (smells), which can attract or repel beetles. A “push-pull” manipulation of the insect – using both repellent and attractant chemicals in tandem – can be used to control unwanted stands of saltcedar, while protecting stands being used by wildlife. To help land managers charged with controlling saltcedar across the west, Rocky Mountain Research Station scientist Sharlene Sing partnered with Montana State University to develop and produce time-release lures used to manipulate the spatial distribution of the tamarisk biocontrol beetle *Diorhabda carinulata* by enhancing its aggregation and intensifying saltcedar defoliation. This semiochemical treatment intensifies *D. carinulata* feeding on saltcedar, causing an increase in foliar dieback and decrease in live canopy. 4-oxo-(E)-2-hexenal produced by saltcedar plants under heavy defoliation by *D. carinulata* has a repellent effect on aggregation of reproductive adults and could be potentially deployed in a timed-release bait to repel beetles in habitats used by endangered bird species. Read more at <https://www.fs.usda.gov/rmrs/science-spotlights/scent-success-beetle-smells-can-help-protect-environment-weeds>



Releasing *Diorhabda carinulata* in eastern Montana. (Photo by Megan L. Hofland, Montana State University)

### **A new yellow toadflax biocontrol agent**

*Rhinusa pilosa*, a stem-galling weevil that attacks invasive yellow toadflax (*Linaria vulgaris*), was recently approved for field release in the United States. This highly promising biological control agent is currently being propagated only at the Rocky Mountain Research Station Bozeman (MT) Forestry Sciences Laboratory for distribution to land managers working in yellow toadflax infested areas throughout the country. The weevil demonstrated 75% reduction in below-ground toadflax biomass was reported in plants galled by *R. pilosa* compared to control plants. This finding is particularly relevant because it indicates that galling might not only compromise the spread of *L. vulgaris* by limiting rhizomatous, clonal stem growth, but also probably reduces multiyear persistence and overwintering survival of the weed. Galled plants were 55% shorter and produced fewer shoots than control plants. Gall tissue represented 40% of aboveground biomass of treated plants, with non-gall mean dry above-ground biomass for control plants. Galling also significantly reduced the potential for sexual propagation of yellow toadflax, with the proportion of flowering stems much lower in treatment vs. control plants, and flowering either fully suppressed or delayed in galled plants. Read more at [https://www.fs.fed.us/rm/pubs\\_journals/2018/rmrs\\_2018\\_tosevski\\_i001.pdf](https://www.fs.fed.us/rm/pubs_journals/2018/rmrs_2018_tosevski_i001.pdf)

### Transferring outcomes of the Great Plains Grassland Summit

The Rocky Mountain Research Station, along with other science and management collaborators, convened a summit of over 200 participants and more than 60 organizations from state and federal agencies, NGOs, industry, and private landowners to better understand stressors and resource demands throughout the Great Plains and how to manage them. In addition, the summit explored collaborative processes for generating new knowledge and for involving producers, conservationists, scientists, and other stakeholders in management decisions. Posters and presentations from the Summit are available [here](#). One of the summit outcomes was a published synthesis of current knowledge based on stakeholder input on key issues facing the Great Plains, viewed here: [Management opportunities and research priorities for Great Plains grasslands](#). Another result is a special edition of articles by plenary speakers in the journal *Rangeland Ecology and Management*, some of which have already appeared online including: [Managing invasive plants on Great Plains grasslands](#); [Energy development and production in the Great Plains: Implications and mitigation opportunities](#); [An assessment of production trends on the Great Plains from 1984 to 2017](#); and [Pollinators of the Great Plains](#).

### Guide to restoring landscapes with western forbs

The Rocky Mountain Research Station, in partnership with the Bureau of Land Management and Great Basin Fire Science Exchange, has prepared an online book, *Western Forbs: Biology, Ecology, and Use in Restoration*, which synthesizes and summarizes research, particularly information and practical experience gained over the last two decades on native forb species occurring in the Great Basin (Nevada, Utah, and Idaho) and beyond. The book aids seed collectors, seed growers, nurseries, landowners, restoration contractors, land managers, and researchers as they increase the supply and use of native forbs and seek knowledge about appropriate species for restoring Great Basin landscapes. The book is comprised of individual chapters that summarize an individual species' biology, ecology, seed technology, and use in restoration. There are 24 species-focused chapters completed, and new species chapters are added as they are completed. The book is available on the Great Basin Fire Science Exchange website (<https://greatbasinfirescience.org/western-forbs-restoration/>) and individual chapters are available in TreeSearch.

### New PhenoMap tool

Monitoring vegetation phenology in New Mexico is important for managers who need phenological information to time activities such as grazing, ecological restoration plantings, control of invasive species, seed collection, and wildlife monitoring. However, tools to deliver timely seasonal development have been limited either spatially or temporally. Rocky Mountain Research Station and Pacific Northwest Research Station scientists developed another option called PhenoMap. This is a weekly assessment of land surface "greenness" across the continental United States that employs the Normalized Differential Vegetation Index (NDVI) derived from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data. We found that PhenoMap effectively tracks phenology on grasslands, shrublands, deciduous broadleaf, and mixed forests. Partners include Northern Arizona University, the University of New Hampshire, and the United States Geological Survey. Read more in: [Monitoring land surface phenology in near real time by using PhenoMap](#).

### Ecological resilience approaches to improve management strategies

Information on ecological resilience can greatly increase the ability to prioritize management activities in those locations where they provide conservation and restoration benefits. Recent research shows that an understanding of an ecosystem's environmental characteristics and its response to disturbance can be used to assess its resilience and risk of ecological threshold crossings. Newly developed approaches that allow managers to evaluate resilience at the scales needed for management and to determine effective management strategies were recently compiled in an e-book in the journal *Frontiers in Ecology and Evolution*. Regional collaborators are the Rocky Mountain Research Station, the Pacific Northwest Research Station, the United States Geological Survey, the Natural Resources Conservation Service and universities, and state agencies. Sagebrush rangelands in Idaho, Nevada, Utah and other western states are the focus of several articles. Read more in: [Operationalizing the concepts of resilience and resistance for managing ecosystems and species at risk](#).

### FireCLIME Tool for assessing ecosystem vulnerability to wildfire and climate change

Fire-climate interactions are complex and mediated by climate effects on vegetation productivity and resulting fuel loads, fuel conditions, and environmental conditions at the time and place of ignition. As part of a larger Joint Fire Science Program project, Rocky Mountain Research Station scientist Dr. Megan Friggens developed the FireCLIME Vulnerability Assessment tool, which scores ecosystems based on current and future expected climate-fire-vegetation relationships as they relate to user inputs about desired future conditions. This tool provides inference on the mechanisms driving vulnerability and which management strategies may be most effective for reducing risk under changing climate conditions. Currently, the FireCLIME tool is in use to assess



Prescribed fire in the Southwestern U.S. (Photo by Rachel Loehmen, USGS)

landscapes on the Santa Fe National Forest and Lincoln National Forest in New Mexico, and the Bighorn National Forest in Wyoming. Read more: <https://www.fs.usda.gov/rmrs/publications/user-guide-fireclime-vulnerability-assessment-va-tool-rapid-and-flexible-system> and <https://www.fs.usda.gov/rmrs/projects/identifying-vulnerability-southwestern-landscapes-changes-climate-and-wildfire-regimes>



Yellow-billed Cuckoo from the Grand Canyon. (Picture courtesy of National Park Service.)

### Suitability maps for western yellow billed cuckoo woodlands

Riparian forests support a disproportionate amount of biodiversity within the southwestern U.S. Climate change and other disturbances are negatively impacting riparian habitats and the species that rely upon them. The western Yellow-billed Cuckoo (wYBCU), listed as threatened under the Endangered Species Act, has declined due to loss and fragmentation of riparian habitats. Arizona is thought to support the largest population of wYBCU. Rocky Mountain Research Station research ecologist Megan Friggens partnered with Tucson Audubon to provide species habitat suitability models for the entire state of Arizona to provide better information on where wYBCU may exist within the state and where these birds might persist under changing climate conditions. For more information: <https://www.fs.usda.gov/rmrs/science-spotlights/modeling-western-yellow-billed-cuckoo-suitable-habitat-arizona-over-next-century>

### New ST-Sim Tool helps managers forecast future rangeland conditions

Rocky Mountain Research Station scientists Paulette Ford and Matt Reeves applied a software-based ecological simulation tool called ST-Sim, short for state-and-transition simulation model, to ask landscape-level “what-if” questions focused on Southwestern rangelands. Using ST-Sim, they projected a variety of conditions, including vegetative state transitions, net primary production, drought likelihood, and forage use and grazing targets. One prediction was that, in grazing areas, drier conditions may quickly cause perennial grass cover to be replaced by weedy annual and sparse grasses. Another prediction was that forage grazing targets for some ecological systems would drop significantly below 35 percent of historic annual production. Based on ST-Sim models, the scientists found that increased drought in the Southwest Region may lead to shrub expansion and transitions between vegetative states, particularly without grazing adjustments. They also determined that ST-Sim can be used to prioritize sites and vegetation types that are candidates for restoration or resilience-building management regimes. Download links, tutorials, and resources at [https://www.fs.usda.gov/rmrs/sites/default/files/documents/sycu\\_tools\\_ST\\_Sim\\_02112020\\_Final.pdf](https://www.fs.usda.gov/rmrs/sites/default/files/documents/sycu_tools_ST_Sim_02112020_Final.pdf)

### Understanding tools that benefit pollinators of the Great Plains

We describe the state of knowledge about responses of pollinators and their foraging and nesting resources to historical natural disturbances and new stressors in the Great Plains. In addition, we also provide information about pollinator management and research needs to guide efforts to sustain pollinators and, by extension, flowering vegetation and other ecosystem services. Although pollinator responses varied, pollinator specialists of disturbance-sensitive plants tended to decline in response to disturbance. Management with grazing and fire overall may benefit pollinators of grasslands. Habitat management and restoration can reduce effects of stressors and augment floral and nesting resources for pollinators. Partners include South Dakota State University, Oregon State University and others. <https://www.fs.usda.gov/rmrs/publications/pollinators-great-plains-disturbances-stressors-management-and-research-needs>

### Using drone technology to census rare plants

Rocky Mountain Research Station scientists partnered with Utah Valley University, Utah Division of Natural Resources, The Nature Conservancy’s White Dome Nature Preserve, the Bureau of Land Management and the United States Fish and Wildlife Service to determine population status of dwarf bear-poppy (*Arctomecon humilis*), which grows only on barren gypsum soils close to a rapidly expanding urban area, St. George, Utah. Key findings of this work include: Dwarf bear-poppy, and likely other rare plant species with distinctive morphology and color that are found in simple plant communities of open habitats, can successfully be censused using drone imagery; Census maps can be combined with habitat classification to examine fine-scale habitat requirements; Drone-based census can provide managers with distribution data over the entire species range, permitting them to better prioritize management activities; and Drone imagery at higher resolution can also be used to carry out yearly monitoring with an image acquisition protocol that will be economical and user-friendly, so that managers will potentially be able to carry out these activities without expert



During a 2-year period, the Rocky Mountain Research Station Shrub Sciences Laboratory in Provo, Utah, produced about 45,000 Holmgren’s milkvetch seeds for introduction studies.

assistance. Similar technological approaches were more recently applied to census and stabilize populations of the endangered Holmgren's Milkvetch (*Astragalus holmgreniorum*). Read more in [Using drone imagery to census a rare desert plant](#) and [Saving Holmgren's Milkvetch: A New Approach for Imperiled Species Management](#)

The Rocky Mountain Research Station, in partnership with the Bureau of Land Management and Great Basin Fire Science Exchange, has prepared an online book, *Western Forbs: Biology, Ecology, and Use in Restoration*, which synthesizes and summarizes research, particularly information and practical experience gained over the last two decades on native forb species occurring in the Great Basin (Nevada, Utah, and Idaho) and beyond. The book aids seed collectors, seed growers, nurseries, landowners, restoration contractors, land managers, and researchers as they increase the supply and use of native forbs and seek knowledge about appropriate species for restoring Great Basin landscapes. The book is comprised of individual chapters that summarize an individual species' biology, ecology, seed technology, and use in restoration. There are 24 species-focused chapters completed, and new species chapters are added as they are completed. The team is working to ensure knowledge transfer and broad distribution of the book such as by posting it on the Great Basin Fire Science Exchange website, a site widely accessed by land managers (<https://greatbasinfirescience.org/western-forbs-restoration/>) and posting individual chapters to TreeSearch.

### **Ensuring future seed availability for restoring the Nation's lands**

The Rocky Mountain Research Station partnered with the University of Nevada, Reno, the Bureau of Land Management, Chicago Botanic Garden, and state agencies to assess seed collections to ensure they will support current and future needs. The Seeds of Success (SOS) is a national seed collection program led by the BLM that started in 2000. The team performed an analysis of the strengths, weaknesses, opportunities, and threats for the SOS program. Assessment of SOS collections shows that SOS has collected seed from over 24,400 native plant populations from ~5600 taxa from Utah and many other states. Over 10,000 seed collections have been shared for restoration and research use. Fire was identified as a significant risk to previously collected populations of native plants, with 3.5% of georeferenced collection sites having burned since collection. Frequency of burning of collection populations increased dramatically since SOS started collecting seed, shifting from ~29 populations to ~48 burning each year starting in 2011. Read more in [Seeds as an investment in the future of US lands](#).

### **Adapting to drought: guidance for managers**

Much of the United States is projected to experience a higher frequency of severe droughts and longer dry periods as a result of a warming climate. Also, warmer temperatures will interact with drought to exacerbate moisture limitation and water stress. Secondary impacts of drought, such as more frequent and larger wildfires and large-scale insect outbreaks, may have even greater impacts (magnitude and spatial extent) than direct drought effects. Hydrological drought is a major concern in areas dependent on reliable flows of surface water for aquatic species and habitats, groundwater recharge, and drinking water supply. However, drought impacts vary regionally, depending on local climate regimes, land use, and other factors. Drought poses major management challenges to resource practitioners and can have substantial impacts on the economy at local and regional scales.

U.S. Forest Service Research and Development published [GTR-WO-98: Effects of drought on forests and rangelands in the United States: A comprehensive science synthesis and translating science into management responses](#), an important publication with wide manager distribution. This General Technical Report summarizes specific drought issues and region-specific management options for increasing resilience to drought for Alaska and the Pacific Northwest, California, Hawai'i and U.S. Affiliated Pacific Islands, Interior West, Great Plains, Northeast and Midwest, and Southeast regions. The report builds on a recent state-of-science synthesis on the effects of drought on forests and rangelands of the United States (GTR WO-93b, 2016), and provides important guidance for evaluating management options to minimize drought impacts. The report emphasizes that optimal responses can be developed by integrating existing policies and practices with new information and by timely reporting of current conditions. If drought-informed practices are institutionalized as part of agency operations, then planning and management will be more effective, and "crisis management" in response to drought can be avoided. RMRS scientists were co-editors of this GTR and co-authors on chapters in this GTR.



GTR-WO-98: Effects of drought on forests and rangelands in the United States: A comprehensive science synthesis and translating science into management responses

### **Skid-trails from post-fire salvage logging contribute to hillslope erosion**

The extent and degree of the soil and vegetation disturbance by wildfire, fire suppression activities, and post-fire management can have long-lasting ecological implications for hydrologic and biological processes. Extended wildfire seasons in the Western U.S. emphasize the need for better understanding of both wildfire impacts and post-fire management on hillslope erosion and watershed responses such as flooding, sediment yield, and debris flows.

Following the 2015 North Star Fire in eastern Washington, Rocky Mountain Research Station researchers used a novel approach to assess impacts of post-fire salvage logging on spatial patterns of hillslope erosion by combining field experiments and remotely sensed imagery. The North Star Fire was part of the Okanogan Complex Fires that burned 209,000 ha — 91,000 ha of which were on the Colville Federation Tribal Reservation and covered nearly 20% of its land base. WorldView-2 satellite imagery was used to relate ground cover and erodible bare soil to measured hillslope erosion using multi-temporal Normalized Differenced Vegetation Index (NDVI) values. Rocky Mountain Research Station researchers found management-relevant impacts when they quantified the influence of skid trails, established during post-fire salvage logging operations, on hillslope erosion. Their results showed that skid trails produced significantly more sediment than either slash treated skid trails or controls with a simulated rill erosion experiment. Similarly, under natural rainfall conditions, sediment yield from hillslope silt fence plots was significantly greater for the skid trail than either the slash treated skid trail or controls. The researchers found that logging slash, applied at a rate to achieve >60% mean ground cover, was an effective treatment to reduce post-salvage runoff and soil erosion and provided recommendations on implementing this practice. Also, significant relationships among NDVI, ground cover, and sediment values suggest that NDVI may help managers evaluate ground cover and erosion potential remotely after disturbances such as a wildfire or salvage logging. Read more here: <https://doi.org/10.1002/hyp.13882>

### **The Aquatic eDNA Atlas: mapping occurrence of aquatic biota**

Effective conservation of freshwater biota during times of rapid climate change, nonnative species invasions, and habitat loss requires precise information about species distributions across broad areas to guide decision-making. Environmental DNA (eDNA) sampling of aquatic environments offers a reliable, cost-effective, and sensitive means of determining species presence if samples are collected following standardized field protocols and analyzed using rigorously designed eDNA assays. Innovative eDNA sampling is being rapidly adopted to address questions about the distribution of species in headwater streams (e.g. boreal toads), the success of nonnative aquatic species removals (e.g., brown trout removal in native trout stream segments), and the range-wide patterns of occupancy by at-risk species, such as bull trout. To foster these efforts, RMRS scientists at the National Genomics Center for Wildlife and Fish Conservation (NGC) and a group of stream scientists based in Boise, ID partnered with dozens of natural resource organizations throughout North America to provide technical assistance in the form of eDNA assay development and field sampling designs for fish, amphibians, crustaceans, mussels, mammals, and birds (<https://www.fs.fed.us/rm/boise/AWAE/projects/eDNAAtlas>). Samples are collected at thousands of sites annually through those partnerships, which has created a large database that is rapidly growing in geographic extent and species diversity. To facilitate access to this database in spatially-explicit formats that maximize the use and sharing of eDNA sampling results, as well as the efficient collection of new samples, the National Fish Wildlife Foundation commissioned the Aquatic eDNAAtlas project and website.

The Rocky Mountain Research Station maintains the website that includes a national grid of potential eDNA sampling sites, available for download, which allows users to view field sampling points that are systematically spaced at ~1-km intervals along river and stream networks across much of the U.S. Each site is assigned a unique identification code in the eDNAtlas database to ensure that it can be tracked and matched to geospatial habitat descriptors and species sampling results. Knowledge of aquatic species occurrence assists in prioritizing stream segments for restoration, removal of nonnative species, and other district and forest-level management decisions.:



Using eDNA sampling to inform fish eradication efforts

Scientists with RMRS's [National Genomics Center for Fish and Wildlife Conservation](#) have developed best practices for application of environmental DNA (eDNA) to fish eradication efforts. [Kellie Carim](#), aquatic research biologist and tribal project Ccoordinator, has been working on brook trout eradication projects using a targeted eDNA approach in Montana with Montana Fish, Wildlife, and Parks, and in eastern Washington in collaboration with the Kalispell Tribe and Washington Department of Fish and Wildlife. Brook trout were introduced to the western U.S. in the mid-1800s and cause negative impacts to native species like cutthroat and bull trout. By using eDNA for eradication projects, managers are now more confidently able to determine when an eradication project has been 100 percent successful. While the most effective way to remove invasive trout is to perform a chemical removal, it is expensive, requires a large crew and large volume of chemicals, and can cause impacts to other organisms, such as invertebrates in the stream. Tools like eDNA can efficiently remove any guesswork about where the target species is and therefore help managers more efficiently mark the area that needs treatment at the beginning of the project, which will reduce the overall treatment area and project costs. These methods have been widely shared with land managers including through [Science You Can Use](#) and a webinar.

### The FIRE-BIRD tool for understanding suitable woodpecker habitat

RMRS scientists have developed the FIRE-BIRD tool, an ArcGIS toolbox to map habitat suitability for disturbance-associated woodpeckers of conservation concern to help inform locations for management activities in predominantly burned forests of the Inland Northwest and Northern Sierras. The suite of species currently included (black-backed [*Picoides arcticus*], white-headed [*Dryobates albolarvatus*], Lewis's [*Melanerpes lewis*], and hairy [*D. villosus*] woodpeckers) makes the GIS tool best suited for postfire management and restoration treatments in dry mixed-conifer forests. Because each woodpecker species requires different habitat characteristics for population persistence in a post-wildfire landscape, these habitat characteristics should be considered when managers are developing salvage logging and restoration projects. Increases in size and severity of wildfire and insect outbreaks are expected to continue with climate change, providing more opportunities for post-disturbance salvage logging and forest restoration activities. We developed [FIRE-BIRD](#), a GIS tool to help managers make the best decisions for maintaining habitat of key wildlife species, while still allowing economic benefits to local communities. This tool was shared widely with land managers through [Science You Can Use](#) and a land manager-focused webinar this year.

### Understanding fire, climate change and management impacts on spotted owls

Scientists at the Rocky Mountain Research Station are helping managers better understand how climate change, wildfire, and forest management interact to drive forest changes and what these changes mean for the ecology and conservation of the Mexican spotted owl. In the Southwest, scientists and managers are working together to find ways to reduce the risk of future megafires while also maintaining critical nesting habitat. Wildfires in the western United States are expected to increase both in size and severity in coming decades and these trends are likely to accelerate large-scale habitat loss and fragmentation for the spotted owl in the Pacific Northwest, California, and the Southwest. All three subspecies that occupy these regions have declined over the last century, and the Mexican and northern subspecies are listed as

threatened under the Endangered Species Act in the United States. Our recent findings include: (1) Within the range of the Mexican spotted owl, a 13-fold increase in area burned is expected by the 2080s; (2) High-severity fire can decrease habitat suitability considerably for nesting Mexican spotted owls; (3) Areas with suitable nesting habitat may be more prone to high-severity fire; and (4) Some types of fire can result in improved habitat for prey and food resources for the Mexican spotted owl, but that improvement may not compensate for the loss and degradation of nesting habitat. We are currently completing a *Science You Can Use* Bulletin and have a land manager-focused webinar planned to broadly distribute findings to land managers.

### **Evaluating Myrtle rust pathogen genetic diversity and invasive threats**

The myrtle rust pathogen poses an invasive threat to tropical and subtropical global regions. RMRS scientists, along with university, land management, and science partners worldwide are using genetic analyses to determine which trees and geographic regions are most at risk. These findings are being shared globally to curb disease expansion. Currently, an invasive myrtle rust disease pathogen (*Austropuccinia psidii*) is spreading around the globe, which threatens native and planted trees and shrubs in the *Myrtaceae* family, such as eucalypt, guava, rose-apple, and 'ōhīa. Though the disease is expanding its geographic range and poses potential threats to forest ecosystems world-wide, we are only beginning to understand the genetic structure of pathogen populations, possible pathways of spread, and potential sources of introductions.

Genetic analyses were conducted on myrtle rust pathogens from eastern Asia, Australia, the Pacific Islands, Florida, United States of America, the Caribbean, Central America, and South America. At least three pathogen biotypes (closely genetically related) were found to occur including a pandemic biotype. The pandemic biotype is present in the USA (as well as Costa Rica, Mexico, Jamaica, and Australia) and is capable of infecting multiple host species. Bioclimatic modeling is being used to predict suitable climate space (potential distribution) of three pathogen biotypes to predict geographic areas where each myrtle rust pathogen biotype poses an invasive threat.



The invasive myrtle rust disease pathogen threatens native and planted trees and shrubs in the *Myrtaceae* family

### **Science-based decision trees for forest managers using mastication**

Mastication is an important tool for reducing fire risk in some situations. Mastication works by reducing forest vegetation into small chunks by grinding, shredding, or chopping material with specialized equipment. RMRS scientists have synthesized the potential benefits of mastication as a forest management tool and presented these findings in the form of a set of decision trees. These decision trees are designed to guide land managers in choosing the right treatment option for a site and management objective(s).

We published a general technical report entitled [To Masticate or Not: Useful Tips for Treating Forest, Woodland and Shrubland vVegetation](#) detailing the most up-to-date information on mastication. A [Science You Can Use Bulletin](#) was created for and distributed to land managers as an easy-to-use companion to the report. Important factors include the type of equipment used, operator experience, and site factors like slope, soils, and presence of nonnative species. Additionally, mastication can increase the abundance of fine fuels and, if ignited, these fuels can smolder for long periods; therefore, mastication may not always be an appropriate forest treatment.

### **Understanding patterns of ponderosa pine regeneration following large, high-severity wildfires**

A group of RMRS scientists, along with collaborators at Northern Arizona and Colorado State University, are investigating factors that influence regeneration of ponderosa pine following large, high-severity wildfires. Many recent wildfires in ponderosa pine forests have burned with high-severity across large, contiguous areas. These high-severity patches stand in stark contrast to the low- and moderate-severity patches that dominated fires in ponderosa pine forests historically, leaving managers uncertain about ponderosa pine's ability to regenerate successfully within them. Elevation, aspect, climate, and the presence/amount of other regenerating vegetation are thought to influence whether ponderosa pine regeneration is successful, due to their influence on the growing environment. Our research is helping managers better anticipate recovery within high-severity patches and, in turn, better determine whether and where post-fire management activities would be needed to maintain ponderosa pine forests in the future. Our results provide insight into how the size, shape, and distribution of high-severity patches may influence recovery patterns for burned ponderosa pine forests. Ponderosa pine forests may recover in portions of high-severity patches that are close to surviving trees, particularly if topo-climatic gradients are also favorable. Farther from surviving trees, recovery may be more apt to be to a ponderosa pine woodland, grassland, shrubland, or forest dominated by sprouting species. Where the return of a ponderosa pine forest is desired but not anticipated to occur, planting may be a viable management strategy. Planting with some level of fine-scale spatial aggregation would best mimic the spatial patterns we observed occurring naturally. A *Science You Can Use* bulletin is currently being developed to share these findings broadly with land managers along with a planned webinar.



## Southern Research Station

The Southern Research Station (SRS) includes research work units across 13 southern states and employs around 300 people, including close to 100 research scientists. SRS research advances many areas of forestry science: the use of prescribed fire; hardwood and softwood silviculture, harvesting, and utilization; protection of drinking water supplies and water quality; sustainable management of wildlife habitat; and the control of insects, diseases, and invasive plants. SRS partners with the Southern Region of the National Forest System to conduct research on a network of 19 experimental forests.

Throughout FY20, SRS focused on research and technology that would foster productive, sustainable use of public and private lands. SRS shared these innovations with partners and stakeholders, including:

- 442 scientific publications
- 101 tours to educational and professional organizations
- 116 presentations to lay organizations
- 351 presentations to research and professional organizations
- 70 articles in the SRS online science magazine, CompassLive
- 200+ posts to more than 5,900 followers on Twitter
- 50+ posts to more than 12,000 followers on Facebook

Some highlights of these outreach, science communication, science delivery, and technology transfer efforts are listed below.



### Science in Practice webinars provide applied take-aways for managers

A new series of thirty-minute webinars highlight recent research and focus on practical management implications for colleagues from the Forest Service Southern Region, Southern Group of State Foresters, and the Southern Research Station. The “Science in Practice” webinar series is a new communication tool

intended to connect scientists, managers, field technicians, and practitioners. Particularly during COVID-19, where travel and in-person meetings are not possible, brief webinars have been a successful tool for sharing research updates. The series began in July 2020 and is averaging 65 attendees per session, with recent sessions attracting more than 100 attendees. Topics have ranged from bat habitat, to invasive species, oak and chestnut regeneration, and remote sensing products. The online webinars are free and available for anyone to attend. Find recordings and key messages from past webinars and upcoming webinars here: <https://www.srs.fs.usda.gov/webinars/science-in-practice/>.

### A new tool for fighting laurel wilt disease

A fungus called *Acaromyces ingoldii* produces potent compounds that inhibit the laurel wilt pathogen, *Raffaella lauricola*, as a team of SRS scientists and partners discovered. Currently, there are limited options available for managing laurel wilt disease and they are generally ineffective for long-term management. This research could lead to new options for managing the spread of laurel wilt disease across the southeast.

In the southeastern U.S., the geographic distribution of laurel wilt disease on redbay, sassafras, and swampbay has expanded rapidly in recent years, with significant ecological impacts on forest ecosystems, and some economic impact on avocado production as well.

Ongoing efforts to address this threat to the southern forests includes exploring potential control measures to reduce the spread of the disease. Routine assessments of fungi associated with bark beetles from loblolly pine led to isolation of an unknown fungus that appeared to have broad-spectrum antifungal activities. The fungus was identified as *Acaromyces ingoldii*, and further investigations showed that the secondary metabolites produced by the fungus significantly inhibited the growth of the laurel wilt pathogen *R. lauricola*. Findings from the study represent a very encouraging preliminary effort in identifying natural compounds with fungicidal/fungistatic activities against *R. lauricola* that could be useful in an integrated management approach against the spread of laurel wilt disease. For more information: <https://www.srs.fs.usda.gov/pubs/59072>.



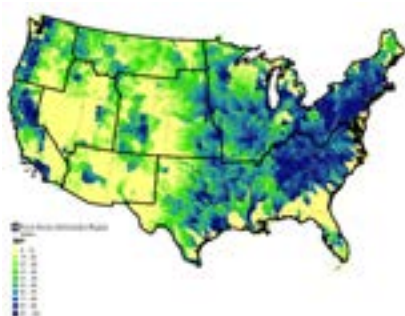
### Bursts of longleaf pine seed production described with a new index

Longleaf pine cone production varies from year to year. Understanding the causes and patterns of this variability will aid in restoration of longleaf pine ecosystems. A burstiness index was developed to help explain some of the ups and downs of cone production. Both longleaf pine and Chinese Torreya produce abundant seed in some years, but not in other years. A good seed production year, or burst, is frequently followed by a longer period of poor seed production. A burstiness index was developed to identify the thresholds and time intervals that indicate seed production bursts. Results indicated that the average time between bursts was longer for episodes of higher seed production for both tree species. Therefore, complex seed production systems may be governed by generic principles that are common to a number of species. Understanding burstiness in tree seed production may provide new knowledge about tree growth dynamics and reproductive behavior. Foresters can estimate when the next episode of high seed production is likely to occur and identify sites with short lulls between periods of high seed production. For more information: <https://www.srs.fs.usda.gov/pubs/59712>.



### Forests to faucets: Visualizing forests' role in supplying drinking water across the U.S.

Forests provide numerous ecosystem services that support the U.S. economy and public wellbeing. In particular, forests provide more clean and stable water than any other land use. To better understand this ecosystem service, SRS scientists and partners in State and Private Forestry and the National Forest System have updated the Forests to Faucets mapping and analysis tool, Forests to Faucets Version 2 (F2F2). The study integrated online maps, watershed models, historic and future projections of climate and land use change, and surface drinking water withdrawal data.



The result is a user-friendly tool that lets forest managers identify important watersheds for drinking water supply based on the population served, forest cover, riparian condition, and hydrology. The tool can also assess threats to water supply under current and future climate and land uses conditions, offering information for protecting or restoring forests that are important for drinking water. The F2F2 maps can be incorporated into broad-scale planning, such as State Forest Action Plans, and can help identify vulnerable watersheds for further local analysis. In addition, information generated from F2F2 can be used in other decision support tools to provide spatial information about surface drinking water management. Ultimately, sound management of forests for clean drinking water supply benefits the American public as a whole. For more information: <https://usfs.maps.arcgis.com/apps/MapSeries/index.html?appid=e84fc83c8be542079d3c1d489d45be21>.

### Hurricane preparedness and recovery guides for southeastern forests, farms, and ranch producers

Each year, hurricanes cause billions of dollars in agricultural and forestry losses, and these losses grow as climate change continues to contribute to more severe hurricane seasons. Producers—farmers, ranchers, and foresters—need to minimize their losses and reduce their post-hurricane recovery time to remain profitable. Existing information on hurricane preparedness and recovery has tended to be scattered and inconsistent. The USDA Southeast Climate Hub worked with university Extension, USDA Forest Service, and Farm Service Agency subject matter experts to develop a centralized resource and make current knowledge and best practices more accessible. The result is a series of 23 guides, focused on the most economically important commodities for all coastal states in the southeastern U.S. The guides include management practices and are designed to reduce economic loss and decrease the time to full recovery.



Each guide begins with steps to build operational resilience to hurricane impacts. This is followed by short- and long-term preparation guidance to help prepare for personal, worker, and operational safety before a hurricane strikes. Finally, each guide provides post-hurricane recovery steps to maximize safety and speed up recovery. As climate change creates more frequent and severe hurricanes, the importance of resources such as these guides will only grow. For more information: <https://www.climatehubs.usda.gov/hubs/southeast/topic/hurricane-preparation-and-recovery-southeast-us>.



## Plant community inventory of the South Fourche Botanical Area in Arkansas ends with a twist

The Ouachita Mountains in Arkansas are home to a number of endemic plant species, many of which are found only in glades, barrens, open woodlands, and river scour-prairies.

The South Fourche Botanical Area was designated by the Ouachita National Forest in 2005 because of its unique plant communities, including a hanging oxbow, a salt lick, several groundwater seepage areas, as well as some high-quality glades, woodlands, and river scour-prairies.

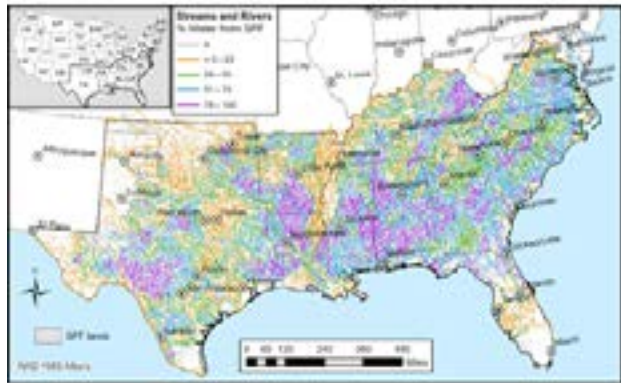
In 2016, Forest Service researchers began a full inventory of the plant diversity of the area. Botanists from the state of Arkansas and The Nature Conservancy joined the effort. Researchers identified eight community types and tallied nearly 700 plant species, including 13 of conservation concern in Arkansas.

Because of the survey, more than 100 new species have been added for the county where this area is located. The Ouachita twistflower (*Streptanthus squamiformis*), previously thought to be limited to portions of three counties in western Arkansas, was found at the South Fourche Botanical area – a 50 mile range extension for a species whose range was only about 30 miles wide. For more information: [https://www.naturalareas.org/2019\\_conference.php](https://www.naturalareas.org/2019_conference.php).

## Quantifying the role of state and private forest lands in providing surface drinking water supply for the southern U.S.

Forests provide the most stable and highest quality water supplies among all land uses. The southern U.S. is heavily forested and the fastest growing region in the nation. Therefore, it is critical to understand the role of forested lands in providing water across the South. Approximately 55 million people in the South –about half the population –derive some portion of their drinking water from state and private forest (SPF) lands.

This study provides a systematic assessment of the interactions among water, forests, and people. Findings highlight the connections between SPF lands, water supply in the South, and the need for sound forest management to ensure clean and stable water supplies for southern communities now and in the future. In addition to peer-reviewed publications, the researchers produced a collection of ArcGIS Story Maps with the South Carolina Forestry Commission. The collection includes interactive maps, data tables, and videos for each of the 13 states and across the South.



The goal is to provide resource managers with information needed to show the important role state and private forest lands play in provisioning drinking water for southerners. Because of the innumerable water-related benefits of forest lands, many water supply authorities seek to maintain forest lands in their watersheds. Healthy forested watersheds protect drinking water quality and minimize water treatment costs. For more information: <https://www.fs.usda.gov/treesearch/pubs/59637>.

## Sawfly GenUS: a new tool to identify woodwasps and other sawflies

Woodwasps and sawflies are pests of many species of plants including hardwood and coniferous trees. Typically, native species are in equilibrium with the ecosystem and are of little long-term concern. Exotic species that have been introduced without natural predators can become major pests. The mostly European, woodboring *Sirex* woodwasp (*Sirex noctilio*) was accidentally introduced to plantations of Monterey pine in New Zealand over 100 years ago and has now become the most significant pest of pines in the Southern Hemisphere including Australia, South Africa, and South America. Some plantations in Australia experienced 80 percent loss due to this species.



The *Sirex* woodwasp was recently discovered near New York, and it is expected to threaten pines in the southeastern U.S. in the future. There are also exotic and native needle- or leaf-feeding sawfly species (*Diprion*, *Neodiprion*, *Pristiphora*) on larch, spruce, and pines and slug-like *Caliroa* species on oaks that can cause severe damage in outbreak years.

Many of these pest species are difficult to identify except by experts, because they superficially resemble benign species. There are about 30 species that resemble *Sirex noctilio* in the Western Hemisphere. Researchers developed an easy to use, online, heavily illustrated tool that enables non-experts like foresters, land managers, and extension agents to identify native and exotic sawflies and woodwasps and determine if they are a threat that requires management. The best way to protect federal, state, and private forests from insect pests is to prevent exotic species from becoming established. This can only be accomplished with tools like Sawfly GenUS to identify native and exotic species. The sawfly tool can be found at: <https://idtools.org/id/sawfly>.

### Scientists embrace shared stewardship to deliver silviculture research

SRS scientists developed, hosted, and participated in a four-day online short course held July 21-24, 2020. The course provided training on the principles and practices of silviculture and closely related disciplines for managing upland hardwood-dominated forests in the eastern U.S.

The course was attended by more than 100 managers from state forestry agencies in Alabama, Georgia, Kansas, Kentucky, North Carolina, South Carolina, Ohio, Tennessee, and Virginia; other federal agencies, including the Department of Defense; and consulting foresters. The course was originally scheduled to be in-person, but the organizers shifted to a virtual format in an effort to disseminate information while keeping participants and speakers safe during the COVID-19 pandemic.

Experts from multiple USDA Forest Service deputy areas, including the Southern Research Station, Northern Research Station, and Forest Health Protection, presented science-based information on a variety of topics. Other presenters were from the University of Tennessee and University of Kentucky.

Presenters discussed regeneration methods and outcomes; forest health; ecological effects of fire in upland hardwood systems; fire effects on timber quality; American chestnut restoration; reviews and drivers of timber production and markets; silviculture effects on wildlife and habitat; and management of oak woodlands, mixed pine-hardwood stands, and degraded hardwood stands.

The course provided land managers with tools and information needed to prepare and implement technically sound silvicultural prescriptions designed to meet multiple objectives. The course was recorded and will continue to provide information to land managers seeking the best available science for actively managing upland hardwood systems. The course is available on the Upland Hardwood Ecology and Management website: <https://www.srs.fs.usda.gov/uplandhardwood/courses-and-webinars/virtual-workshop/>.



### The Southern Pine Module goes virtual

Every two years, SRS scientists are invited by experts in the Southern Region of the USDA Forest Service to host the Southern Pine Module, a ten-day, field-based workshop that highlights the ecology and management of loblolly, shortleaf, slash, and longleaf pines on public lands across the South.

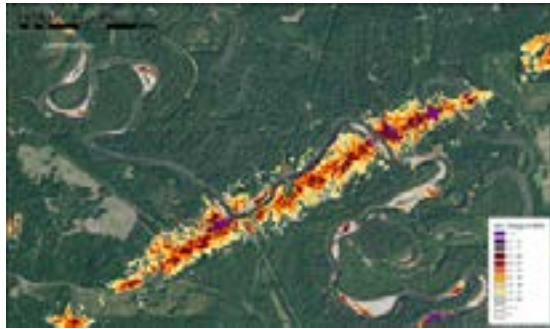
The goal of the module is to provide the advanced education and training that agency foresters need to obtain the silvicultural certification required to conduct active management on federal lands. Due to safety protocols and travel restrictions during the COVID-19 pandemic, coordinators converted the module into a virtual online event, featuring four hours of presentations and daily discussions across the ten-day session.

Topics ranged from advances in active forest management strategies and tactics, to markets and economics, and management of genetic resources used in planted stands. Experts also discussed invasive and destructive plants and insects such as Chinese tallow tree and the southern pine beetle.

Although participants missed being in the field, organizers created photo-based virtual field tours in forests where southern pines are managed. One tour stop dated back to the early 20th century using photos and citations from the “Life History of Shortleaf Pine,” a 1915 USDA Bulletin by W.R. Mattoon. His descriptions of shortleaf pine a century ago can help guide current efforts to restore that iconic species across the landscape to which it is adapted.



The virtual sessions were recorded, so land managers across the Southern Region can use the recorded sessions in their own training and continuing education activities. The presentations and recordings are available: <http://fsweb.srs.fs.fed.us/nasp-module/>. For more information: <https://www.srs.fs.usda.gov/compass/2020/08/25/the-southern-pine-module-goes-virtual/>.



### **Monitoring forest health during a pandemic: satellite-based remote sensing fills a crucial gap**

Assessing damage from natural disturbances is an ongoing need for state and federal forest managers. Before the 2020 growing season began in the South, tornadoes struck from Texas to North Carolina. Two sequential frosts set back the growing season across Tennessee, Kentucky, and Virginia. As the summer went on, vast sections of Michigan and New York were defoliated by the nonnative gypsy moth, then hurricanes inundated low lying areas of the South.

For decades, the USDA Forest Service and state agencies have tracked disturbances such as these in partnership, primarily through aircraft and ground observations. Those capabilities were curtailed in 2020 by coronavirus restrictions. The forest monitoring mission would need to rely on existing and new remote sensing technologies during the pandemic.

Southern Research Station researchers stepped up to this challenge by working closely with state and federal partners to ensure maximum use of existing ForWarn products and the

new HiForm workflow that makes use of high-resolution satellite imagery. Researchers worked closely with partners to map damage and build capacity through free sharing of analysis tools and one-on-one exchange. This communication helped managers track disturbances and provided additional insights for the researchers. Given the long-term cost savings and safety benefits of rapidly evolving remote sensing technologies, this intense 2020 team effort should continue to reap rewards for years to come. Explore the tools at <https://forwarn.forestthreats.org/> and <https://hiform.org/>.

Improving technology transfer for land managers: a new approach focused on the American chestnut

Forest management requires the best available scientific information, but obtaining this information can be challenging, especially as budgets shrink. In order to meet these information needs without cost to land managers, an SRS research forester is developing an online educational course – as well as processes that others can readily apply to share relevant research results.

One interactive educational course is complete and provides information on the ecology, silvics, and the demise of the American chestnut (*Castanea dentata*), a tree that once dominated 200 million acres of the eastern U.S.

The course includes glossaries, downloadable documents, a bibliography, audio accompaniment, and videos. The course will be peer-reviewed and published online through AgLearn for USDA users and on a separate website for state foresters, private landowners, and other users outside the agency. Course surveys and assessments will be used to track user groups, refine and improve the course, and develop future courses.

Technology transfer products, such as this online educational course, allow the Forest Service to excel as a high-performance agency by providing easily accessible and engaging training to National Forest System managers. Additionally, the knowledge shared through the course can benefit the public. For more information: <https://srs.fs.usda.gov/products/courses/#chestnut>.

**An integrated management strategy for hemlock woolly adelgid is now available**



A nonnative invasive insect, the hemlock woolly adelgid (HWA), threatens the ability of natural resource managers to maintain eastern and Carolina hemlocks as critical components of unique forest ecosystems in eastern North America. Although substantial progress has been made in both chemical and biological control of HWA, neither of these tactics applied alone is expected to provide adequate control of HWA throughout its introduced range.

A new USDA Forest Service resource manager's guide titled Integrating Chemical and Biological Control of the Hemlock Woolly Adelgid presents a strategy for using biological and chemical control together in the same forest stands. The goal of the strategy is to prolong hemlock health on certain hemlock trees through temporary insecticide protection, while simultaneously establishing predators on nearby untreated trees. Temporarily-protected hemlocks are expected to eventually support predators after their chemical treatment wears off. Guidelines for site selection, treatment timing, spatial considerations, monitoring, and assessment are included. The guide is intended as a starting point for a more sustainable approach to HWA management that reduces the amount of insecticide applied and that can be integrated with additional management tools as they are developed. For more information: <https://www.fs.usda.gov/treearch/pubs/59529>.



## Technology and Development Centers (Missoula and San Dimas)



### History

Originally tasked with repurposing surplus military equipment to aid in fighting wildfires, the National Technology and Development Program (NTDP) started life as equipment development centers located in Missoula, MT and San Dimas, CA. These equipment development centers were responsible for many of the life- and cost-saving advances common to today's firefighters: standardized hoses, pumps, couplings, rappelling and parachuting equipment, and the essential fire shelter, credited with saving more than 300 lives on the fire line.

The center's scope eventually expanded beyond wildfire, and the centers were combined into one organization: the National Technology and Development Program. Today, the program works on projects touching on forest management, recreation, engineering, occupational safety and health and more.

The National Technology and Development Program now categorizes its work within three areas: application of innovative science and technology, knowledge synthesis, and specifications and standards.

The Mission of the National Technology and Development Program is to provide Forest Service employees and partners with practical, science-based solutions to resource management challenges by developing and managing specifications and standards, synthesizing and sharing knowledge, and applying innovative science and technology.

To support the Technology and Development Program's mission, the Program has a cadre of personnel with far-reaching skills. Engineers, technicians, foresters, biologists, draftsmen, writers, and publishers all work as project team members to support the problem-solving goals of the program.

The Program serves as a resource to three of the four deputy chief areas in the Forest Service: National Forest System, Business Operations, and State and Private Forestry.

The program partners with the fourth deputy chief area, Research and Development, as well as academia, private industry, and other governmental agencies to achieve its mission. The Program's team approach to creative problem solving has resulted in some unique and innovative solutions. Some of those solutions include:

- The Sweet Smelling Toilet
- Redesigned Fire Shelter
- Water-Based Tree Marking Paint
- Improved Helicopter Rappel Rope and Descender
- Electronic Forms for National Visitor Use Monitoring
- Machine Vision System for Forest Management (Patent & CRADA)
- Augmented and Virtual Reality Based Training
- Fueling Systems for Small Engines (CRADA)



## **International Institute of Tropical Forestry**

The International Institute of Tropical Forestry (Institute) is housed in San Juan, Puerto Rico where it serves people from Puerto Rico, the U.S. Virgin Islands, the Caribbean, and central and south America. The Institute has an international mission as well as Research & Development and State and Private Forestry missions. It has been a unit of the Forest Service since 1939 and it specializes in tropical forestry, a specialty for which it is globally known given the level of excellence and continuity of its programs. As an example, the Institute pioneered tropical forestry in this hemisphere and developed the field at a time when there was no professional tropical forestry being practiced in the region. Today, the programs of the Institute support the Forest Service mission in the only tropical forest in the National Forest System, the El Yunque National Forest. This forest is also an experimental forest in its entirety (unique in the agency) and is the most-studied tropical forest in the hemisphere. The results of the research program of the Institute are broadly transferred to a diverse network of collaborators including non-governmental organization, municipal and state governments, landowners, land management practitioners, international organizations, and other scientists, to name a few. Through electronic media, the Institute now reaches millions of people.

### **Recent outcomes of Institute programs include:**

Comprehensive understanding of the effects of hurricanes on tropical forests, including uncovering invisible effects through microbial action that may prove key to processing enormous quantities of debris produced by hurricanes and other extreme events.

Established the first experiment dealing with the response of tropical forests to increases in air temperature. Experiments on the effects of droughts and fire on tropical forests are also underway and yielding information relevant to forest conservation.

How do cities think? How can cities be made more adaptive and resilient to extreme events? These questions are being addressed through networks of tropical and temperate cities. Research shows that tropical cities are different from temperate cities in terms of their green infrastructure and social-ecological responses to extreme events. The Institute transfers the results of its research to collaborating communities and landowners through programs that include tree cities, forest stewardship management plans, urban councils, land acquisition for conservation purposes, and new eco-tourism enterprises; all are programs that provide jobs and economic development to people.

The Institute also has a conservation education program that reaches underrepresented populations from kindergarten to post-doctoral levels.

## 6.13 Metric Tables.

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

Forest Service (FS)	FY2016	FY2017	FY2018	FY2019	FY2020
<b>Total number active CRADAs<sup>1</sup></b>	73	74	22	58	102
<b>Number newly executed CRADAs</b>	33	34	9	36	50
All other Non-CRADA/MTA Agreements	ND	ND	ND	ND	2,872

1. Starting in FY 2019 the Forest Service will count all agreements under the authority of 15 U.S.C. 3710a as CRADAs

**TABLE 2. Invention Disclosure and Patenting**

Forest Service (FS)	FY2016	FY2017	FY2018	FY2019	FY2020
<b>Total number new invention disclosures<sup>1</sup></b>	24	20	10	9	12
University co-owned	2	7	1	2	5
<b>Total number patent applications filed<sup>2</sup></b>	12	11	7	7	10
University co-owned	7	6	0	1	5
<b>Total number patents issued</b>	9	5	5	3	4
University co-owned	4	4	4	0	0

1. Inventions arising at the federal lab.

2. Includes U.S. patent applications, foreign patent applications filed on cases for which no U.S. application was filed, divisional applications, continuation-in-part applications, and provisional applications.

**TABLE 3. Profile of Active Licenses** \*ND-no data available.

Forest Service (FS)	FY2016	FY2017	FY2018	FY2019	FY2020
<b>Total number active licenses</b>	19	19	9	11	13
Executed to small businesses	2	2	1	0	ND
Executed to startup businesses	1	1	1	0	ND
Executed to universities	16	16	1	0	ND
<b>Invention licenses</b>	19	19	9	11	13
Executed to small businesses	2	2	1	0	ND
Executed to startup businesses	1	1	1	0	ND
Executed to universities	16	16	1	0	ND

ND = In progress but not signed

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

Forest Service (FS)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
<b>Total number of income bearing licenses</b>	21	19	19	9	11	13
Exclusive	20	18	18	9	11	13
Partially exclusive	0	0	0	0	0	0
Non-exclusive	1	1	1	0	0	0

**TABLE 5. Income From Licensing**

Forest Service (FS)		FY2016	FY2017	FY2018	FY2019	FY2020
<b>Total income all active licenses</b>		\$2,878	\$2,634	\$3,122	\$800	ND
Invention licenses		\$2,878	\$2,634	\$0	\$800	ND

1. Invention licenses refer to licenses resulting from a patent.

2. Other IP licenses included biological materials licenses and plant variety protection licenses.

\*ND-no data available.

**FY20 FS Accomplishment Metrics in support of the REE Action Plan**

Fiscal Year: 2020		
Products (Software/Web & Multimedia), Peer Reviewed and Non-Peer Reviewed Publications		
<b>Outcomes</b>	<b>Product Type</b>	<b>Total Entries</b>
Publications	Formally Refereed	1179
Publications	Informally Refereed	591
Publications	Non-Refereed	135
Publications	All types	1905
Publications Articles	In Journals	1152
Publications Articles	Not in Journals	753
Science Delivery	Activities	1194
Science Delivery	Products	239

