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A Century of Innovation and Service

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Science Serving Society

The Research and Development (R&D) Deputy Area of the Forest Service, an agency of the U.S. Department of Agriculture (USDA), works at the forefront of science to improve the health and use of our Nation's forests and grasslands. Research has been part of the Forest Service mission since the agency's inception in 1905. Today, about 500 Forest Service researchers work in a range of biological, physical, and social science fields to promote the sustainable management of the Nation's diverse forests and grasslands. Their research covers a lot of territory, with programs in all 50 States, U.S. territories, and commonwealths.

Forest Service research supports the agency's priorities and has a steady focus on informing policy and land-management decisions. People have a growing recognition of the critical services that forests provide, including clean air and water, carbon sequestration, wildlife habitat, and opportunities for outdoor recreation. But forests are threatened by a multitude of stressors, even as demand for them grows. As a result, the Forest Service has placed great emphasis on functional restoration: the cultivation of healthy, resilient forests capable of delivering all the benefits that people appreciate and have come to expect. Forest Service scientists are actively finding ways to address these challenges, whether by managing for invasive insects and diseases, restoring degraded river ecosystems, or developing sustainable ways to harvest forest products. The information and technology produced through basic and applied research programs are available to the public for its benefit and use.

Forest Service research is carried out through seven regional research stations, including the Forest Products Laboratory in Madison, WI, and the International Institute of Tropical Forestry in San Juan, PR. Forest Service scientists partner with colleagues in the agency's other mission areas and with other USDA agencies, including the Agricultural Research Service, the National Institute of Food and Agriculture, and the National Agricultural Statistics Service. Forest Service Research and Development (R&D) also partners with other Federal agencies, industry, academia, tribal governments, and nonprofit organizations.

The Foundation of Forest Service R&D

As the research arm within a land management agency, Forest Service R&D has an intimate connection to the land and an opportunity to inform land management decisions through the application of science. Long-term research is the foundation of Forest Service R&D. Two critical resources help to make this longstanding research possible: (1) a vast network of experimental forests and rangelands and (2) the Forest Inventory and Analysis (FIA) program, an annual census of the Nation's forests.

The Forest Service maintains a network of 81 experimental forests and rangelands that extends from St. Croix in the U.S. Virgin Islands, up to Alaska, all the way over to Hawaii, and down to the Deep South.

This broad spread includes nearly 50 degrees of latitude, which results in a wide range of temperature and precipitation conditions. Ecosystems vary from a boreal forest in Alaska to a tropical forest in Puerto Rico and a dry desert range in Utah. These living laboratories support a diverse portfolio of applied and basic studies with short- and long-term planning horizons. These studies use a range of approaches, including manipulating the environment, making long-term observations, conducting simulation modeling, and studying life history. The dominant research themes have focused on timely issues related to the use and conservation of natural resources. Today, the focus is on water, wildland fire, wildlife habitat, and the impacts of a changing climate on natural resources.

The FIA program provides information about the condition of and trends in forest health. The McSweeney-McNary Act of 1928, which formally established a research organization in the Forest Service, also provided a legal mandate for the FIA program. It directed the USDA Secretary to conduct and keep current a comprehensive survey of the present and prospective requirements for timber and other forest products in the United States and of timber supplies.

Mission

The Research and Development mission of the Forest Service is to develop and deliver knowledge and innovative technology to improve the health and use of the Nation's forests and grasslands—both public and private.

FIA reports on the status and trends in forest area and location; species, size, and health of trees; total tree growth, mortality, and removals by harvest; wood production and utilization rates by various products; and forest land ownership. The report also projects how forests will appear 10 to 15 years from now, which helps determine whether current forest management practices can sustain forests in the long run. Forest Service R&D manages FIA in cooperation with the agency's State and Private Forestry (S&PF) and National Forest System (NFS) Deputy Areas.

The experimental forests and rangelands and the FIA program have generated huge datasets that go back decades. The size and richness of these datasets mean that Forest Service scientists have documented a long history of changing disturbance regimes such as droughts, hurricanes, and wildland fires.

This knowledge enables them to assist land managers inside the Forest Service and beyond in management and restoration efforts. Because so much of the land serves as habitat for wildlife and fish, Forest Service efforts aid threatened and endangered species as well.

For example, Forest Service scientists tracked the response and recovery of tropical forest herb, shrub, and vine communities to multiple hurricanes spanning 21 years across the Luquillo Experimental Forest in Puerto Rico. This remarkable, long-term study provided evidence that hurricanes alter the composition of nontree species by promoting the dominance of rapidly spreading ferns and vines. These big datasets also draw in external individuals and groups conducting ecological research. In the past few decades, the Forest Service has moved a subset of its experimental forests and rangelands into a system of ecological observatories by cooperating with other networks, such as the Long Term Ecological Research Network, National Ecological Observatory Network, and the National Aeronautics and Space Administration, and by collaborating with other agencies and external scientists, many of whom are supported by the National Science Foundation.

National Research Focus Areas

Forest Service R&D focuses the bulk of its research capacity on areas of national importance, including wildland fire and fuels; water, air, and soil; wildlife and fish; invasive species; outdoor recreation; forest inventory and monitoring; and resource management and use. The fiscal year (FY) 2015 enacted budget provides $296 million for the Forest and Rangeland Research appropriation, which includes $70 million for the FIA program. Some research projects that highlight the depth and breadth of Forest Service R&D are presented in the following sections.

Restoration

Forest Service R&D is enhancing and integrating science capabilities and results across disciplines to inform functional restoration efforts and make them more effective and efficient. Functional restoration emphasizes the restoration of abiotic and biotic processes in degraded ecosystems through management actions designed to achieve desired functions and address changing climate conditions.

Forest Service research addresses key questions surrounding functional restoration for diverse ecosystems, including grasslands, forests, and watersheds, in response to disturbances such as fire, pests, and diseases.

Forest Restoration Efforts Yield Climate Benefits

In Douglas-fir and true-fir dominated dry mixed-conifer forests of the Northwest, implementing selective harvest and surface fuel treatments generates greater climate benefits when accounting for in- and out-of-forest effects on greenhouse gases.

A stand of grand fir and Douglas-fir in eastern Oregon. (Photo by Dave Powell, USDA Forest Service)

Forest Service restoration science activities help do the following:

- Quantify realistic expectations and outcomes for restored systems by evaluating tradeoffs and synergies.
- Determine what changes in structure, functions, and processes are needed to accomplish the necessary changes.
- Develop and test management options, systems, practices (e.g., fuels reduction treatments), and products (e.g., bioenergy) for sustainably delivering intended outcomes at the desired spatial and temporal scales.
- Provide science and landscape-scale decision-support tools to help landowners and managers ensure that restoration activities will yield a meaningful return on investment.
- Develop growing stock that will be adapted for restoration efforts, anticipating for expected environmental conditions, human needs, pests, and diseases.
- Work with stakeholders to establish realistic goals that are adapted to future conditions.

Using a Landscape Model for Planning Red Spruce Restoration in West Virginia

Forest Service scientists developed a model to answer specific questions about meeting restoration goals for red spruce while protecting habitat for the Virginia northern flying squirrel. Scientists designed the patch cuts modeled in this experiment to be close to the intended restoration actions. The harvests modeled show that hands-off approaches to threatened or endangered species habitat can delay progress on restoration goals in this red spruce-dominated landscape.

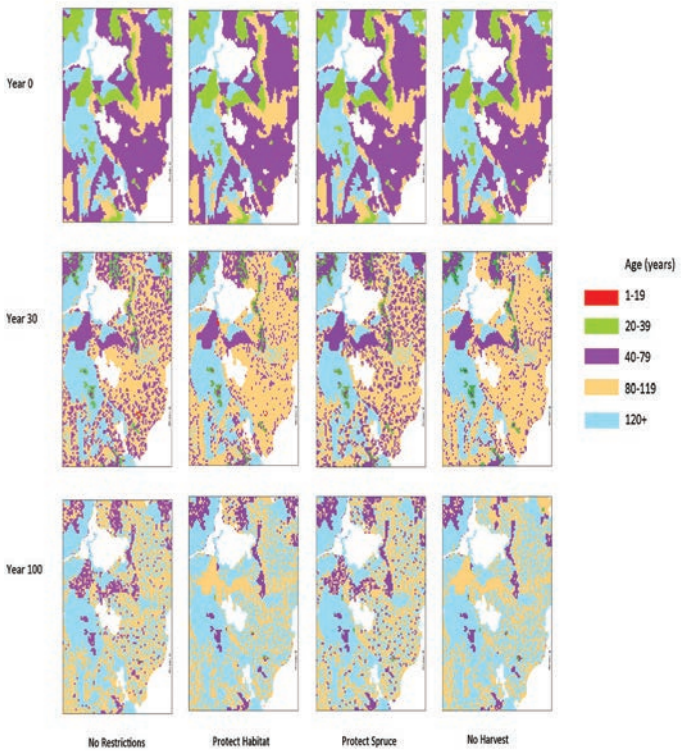
Many Bird Species Benefit From Oak Savanna Woodland Restoration

Many bird species of conservation concern in the Midwestern United States are associated with early successional or open forest conditions that are maintained by disturbance, such as fire or timber harvest. Growing interest in restoring savannas and woodlands in the Midwest for a variety of objectives can benefit many of these bird species.

Oak savanna and woodlands are being restored through the use of prescribed fire and tree thinning and provide habitat for many birds of conservation concern. (Photo by Jennifer Reidy, University of Missouri)

Provisional Seed Zones Developed To Guide Seed Source Decisions for Restoration of Native Species

Forest Service scientists developed generalized provisional seed zones that can be applied to any plant species in the United States to help guide seed movement. The proposed provisional seed zones delineate areas of climatic similarity, which when combined with areas of general ecological similarity as delineated by ecoregions, may be effective as a starting point for guiding seed transfer of species used in restoration.



Changes in age classes for red spruce and red spruce-northern hardwood forest types combined for a section of the study area (about 13,000 acres) at three time steps. (Photo by Melissa Thomas-Van Gundy, USDA Forest Service)

A volunteer collects seed from bluebunch wheatgrass in the Blue Mountains, WA, as part of a study to develop seed zones and population movement guidelines. Bluebunch wheatgrass is often used to restore rangeland and burned forested areas.
(Photo by Brad St. Clair, USDA Forest Service)

Inventory, Monitoring, and Analysis

The mission of this research is to provide the resource data, analysis, and tools needed to effectively identify current status and trends, management options and impacts, threats, and other natural processes to enhance the use and value of our Nation's natural resources.

Forest Inventory and Analysis Program

FIA uses remote sensing and sampling to track forest health and productivity on all U.S. lands, public and private. The information gathered includes tree cover; species ranges and diversity; forest land uses; and tree age, size, growth, mortality, and harvest. FIA tracks the forest products sector by surveying all mills on wood consumption and production. This information is vital to the forest sector for infrastructure planning and maintaining global competitiveness. The FIA program also provides the national forest carbon estimates required by the U.S. Environmental Protection Agency and the U.S. State Department to satisfy international reporting requirements. The program monitors and reports on health and sustainability indicators of U.S. forests for the United Nations and for global reporting mechanisms.

Some accomplishments follow—

- FIA data have underpinned hundreds of millions of dollars in economic development in the forest sector and homebuilding industries that has provided tens of thousands of jobs and millions of homes for Americans (a more than thirtyfold return on investment).
- Of the Nation's forests, 58 percent are in private ownerships that supply 92 percent of the Nation's forest products. FIA monitors the forest health and productivity and the attitudes and objectives of private forest landowners to support development of sound policies. These forests also provide key measures of watershed conditions, wildlife habitat, and the wildland-urban interface (WUI).
- In FY 2014, Forest Service R&D implemented FIA annual forest sampling in all 50 States in response to strong support from State foresters, firefighters, and the forest industry. The recent Farm Bill legislation expands the FIA program's mandate to monitor urban areas, which will provide seamless WUI data to improve fire risk management efforts and our understanding of land use change trends.

The Resources Planning Act Assessment

The Resources Planning Act (RPA) Assessment, published most recently for 2010 and updated in 2012, reports on the status and trends of the Nation's renewable resources on all forest and rangelands, as required by the Forest and Rangeland Renewable Resources Planning Act of 1974. The RPA Assessment is nationally consistent, spatially explicit, and multifaceted, and it includes analyses of forests, rangelands, wildlife and fish, biodiversity, water, outdoor recreation, wilderness, urban forests, and the effects of climate change on these resources. The 2010 RPA Assessment uses a scenario approach to look at the major drivers of change on renewable resources: economic development, population growth, climate change, and land use change. The assessment also looks at the potential vulnerability of water supplies, wildlife habitat, recreation, and forest and range resources.

National Report on Sustainable Forests

This periodic report provides a comprehensive overview of U.S. forest conditions regarding the ecological, social, and economic dimensions of sustainability. The report is designed to inform and facilitate public dialogue and decisionmaking about moving the United States toward the goal of sustainable forest management. A 2015 update of this report is being prepared.

Water, Air and Soil

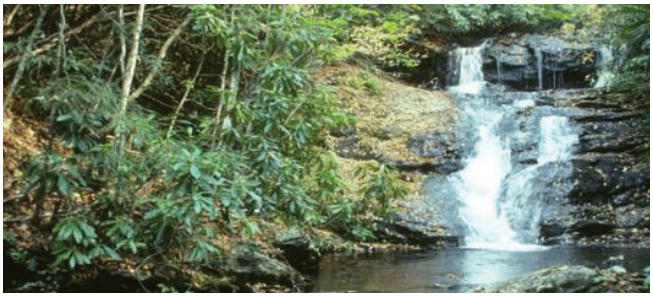
This research provides the scientific basis and specialized tools needed by natural resource managers and landowners to understand the likely effects of their decisions on the Nation's water, air, and soil resources on forests and rangelands. The applied research conducted by Forest Service R&D contributes to a better understanding of the interactions among changing land uses, weather patterns, and pollution levels.

Water Quantity and Quality

Upon the founding of the Forest Service, one of the new agency's missions was to protect our Nation's headwaters. Today, the provisioning of water of sufficient quality and quantity remains integral to our work. Forested regions are a significant source of public drinking water. The quality of that water is controlled by hydrologic pathways from the atmosphere to the faucet. These pathways, and therefore water quality, are altered through changes in land management, use, and disturbance. Forest Service researchers conduct long-term water quality studies at scales from plots to watersheds, allowing us to understand these processes.

Quantifying the Role of NFS Lands in Providing Surface Drinking Water Supply for the Southern United States

In the South, as in the rest of the United States, people and communities depend on forests as the headwaters for a clean and dependable water supply. A new publication, Quantifying the Role of National Forest System Lands in Providing Surface Drinking Water Supply for the Southern United States, by Forest Service researchers provides details at the landscape level on the quantity of water southern communities receive from Federal, State, and private forest lands. The report provides, for the first time, scientifically credible information on the exact extent and importance of forests to drinking water in the South.



Forests and water are inextricably linked, and forested watersheds provide clean and dependable water supplies to downstream communities. (Photo courtesy of USDA Forest Service)

Forest Service biological scientist Johnny Boggs studies the impacts of nitrogen deposition on nutrient cycling and forest productivity in eastern U.S. forests.

Lichens Indicate Air Quality Near Natural Gas Wells

Nitrogen in lichen tissues closely correlates with measured nitrogen deposition in forests near natural gas wells in the Bridger Wilderness, WY. The Clean Air Act mandates that Federal land managers protect air quality-related values for Federal Class I parks and wilderness. The mandate involves assessing the impact of new pollution sources and reporting it to local regulators. This Forest Service study was the first to validate use of lichen tissue indicators for assessing nitrogen in dry interior forests and for detecting low-level nitrogen inputs from oil and gas operations.

Wolf lichen (*Letharia* spp.) is a species frequently used to estimate nitrogen deposition in western forests. (Photo by Jason Hollinger, Wikimedia Commons)

Resource Management and Use

This research focus area provides science and technology that help sustain forests and grasslands in the United States and keep them economically and environmentally productive. This research seeks to maximize the environmental benefits provided by forests and grasslands by enhancing land values, supporting traditional and emerging forest products that contribute to the U.S. economy and American quality of life, and encouraging rural development through local business growth and job creation.

Ecological Limits to Biomass Harvesting

Removing forest biomass for fuel can provide an alternative to fossil fuels and may mitigate atmospheric carbon dioxide increases, but it may change ecosystem functions. Forest Service scientists and their research partners showed that different levels of removal of forest biomass affect soil and tree productivity. The project provides managers with the information needed to prevent or mitigate negative effects of biomass harvesting.

Harvest for woody biofuels. (Photo by Anthony D'Amato, University of Minnesota)

A Simple Technique To Improve Woody Biomass Quality

The commercial markets for biofuels and biobased products will require cost-competitive raw materials to compete with rival energy sources. The Forest Service continues to work on identifying ways to improve feedstock logistics.

Forest Service research economist Evan Mercer conducts economic and policy analyses of the effects of government policies, market factors, and societal values on forest resources. His research focuses on the United States, as well as developing countries like Lesotho, Africa, where he analyzed the value of preserving alpine wetlands.

In 2014, Forest Service scientists examined a method to improve biomass quality using a simple drying technique. Results indicate that the final moisture content measured in a plantation of young southern loblolly pine trees studied was lower in the smaller scattered bunches than in a large pile. To translate this to a real-world application, a logging contractor could increase the value of biomass deliveries by felling and bunching trees, then delaying the skidding and processing phase for a number of weeks to allow natural drying.

Loblolly pine is frequently harvested for use as a biofuel. (Photo by Erich Vallery, USDA Forest Service)

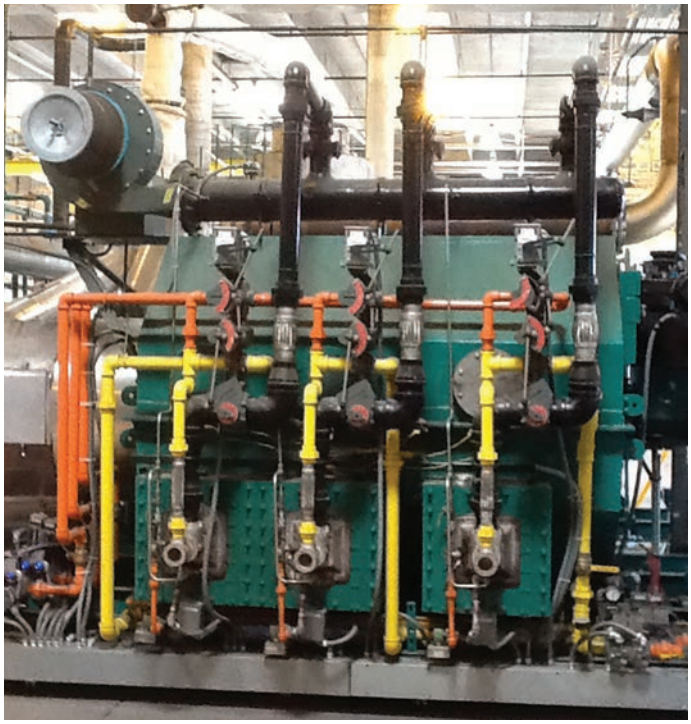
Adaptation Demonstrations Provide Real-World Examples of Climate Change Response

Climate change will have long-term effects on forest ecosystems and the services they provide. High-quality scientific information is critical, but this information also needs to be integrated into natural resource management. The Northern Institute of Applied Climate Science, a multi-institutional effort led by the Forest Service, worked with partners to create adaptation demonstrations of real-world examples of how forest landowners and natural resource professionals are adapting forests to changing conditions.

Science teachers visit an adaptation demonstration project developed by the Bad River Natural Resources Department, Bureau of Indian Affairs, and Northern Institute of Applied Climate Science. (Photo courtesy of G-WOW team, Eli Sagor, Sustainable Forests Education Cooperative)

Novel Technology Uses Waste Wood To Make Bioenergy While Sequestering Carbon

Wood companies need high-value uses for wood residues. A new technology developed by Forest Service researchers and their partners converts wood residues into high-value products such as biochar—a solid material obtained from the carbonization of biomass while producing bioenergy. The researchers are measuring the environmental impacts of this new wood technology compared with current fossil-fuel technologies.



The Tucker Renewable Natural Gas unit is a new bioenergy technology that uses wood such as forest biomass as its fuel source. (Photo by Richard Bergman, USDA Forest Service)

Climate Change Effects

Climate change will have long-term effects on forest ecosystems and the services they provide.

Agroforestry

Agroforestry is a land management approach that blends agriculture and forestry, where appropriate, to build healthier, more profitable, and more climate-resilient farms, ranches, and communities.

The USDA National Agroforestry Center (NAC) is a three-way partnership between two arms of the Forest Service—R&D and S&PF—and the USDA Natural Resources Conservation Service. Its mission is to accelerate the application of agroforestry through a national network of partners. Through research, technology development, tools, training, and outreach activities, the NAC team provides useful products and services for the advancement of agroforestry. Key customers are the natural resource professionals who work with farmers, ranchers, woodland owners, tribes, and communities.

A Win-Win on Agricultural Lands: Creating Wildlife Habitat Through Agroforestry

More than 50 percent of land use in the United States is dedicated to agricultural production. Farms and ranches, therefore, are a critical piece in the conservation puzzle, because actions taken on these working landscapes affect wildlife and the health of ecosystems. Agroforestry is one option for creating benefits for landowners and wildlife.

Blue blooms of native California lilac and other native shrubs form part of a 1-mile hedgerow in Yolo County, CA. Hedgerows, an agroforestry practice, increase pollination activity from native bees and provide crop protection by harboring beneficial native insects over crop pests by a margin of three to one. (Photo by Jessa Cruz, Xerces Society)

Biomass Equations for Agroforestry's Working Trees

A collaboration between the Forest Service and the University of Nebraska is providing a basis for determining the most efficient and accurate way to account for the immense carbon (C) contributions made by agroforestry's Working Trees concept, which was developed by the Forest Service to communicate the role that trees play in agricultural systems. One of the first such efforts in the United States, this project will help landowners participate in voluntary reporting and future C markets.

An established windbreak on a farm in Colorado. (Photo courtesy of USDA Forest Service)

Precision Design for Improving Buffers and Water Quality

The effectiveness of vegetative buffers, conventionally designed to have uniform width along field margins and riparian areas, can be improved by placing a relatively wider buffer at locations where pollutant loads are greater. Forest Service scientists developed a Geographic Information System (GIS) tool that accounts for nonuniform flow and produces variable-width designs that are more effective. Case studies using this GIS tool showed that precision design could double the effectiveness of buffers over traditional constant-width designs. Through terrain analysis, this GIS tool produces designs that can substantially improve the water quality performance of vegetative buffers.

Riparian forest buffer planting along streambank in Bear Creek, IA. (Photo by Richard Straight, USDA Forest Service)

Urban Natural Resources Stewardship

Improving the sustainability and livability of cities is a long-term challenge and goal across the United States and internationally. Municipal leaders are embracing nature as a critical component of the urban environment and of the health and well-being of a city's residents. Forest Service scientists are at the forefront of urban forestry and watershed research, providing science that helps communities improve their natural resources and facilitate a transition to a more sustainable future.

Some accomplishments follow—

- Forest Service R&D continues to refine the i-Tree software suite, an internationally recognized application tool for valuing urban tree benefits. i-Tree is now used in more than 110 countries.

- In FY 2014, the Forest Service FIA program teamed up with i-Tree to expand FIA to urban areas, beginning in Baltimore, MD, and Austin, TX. This strategic urban forest inventory will monitor urban forest status and trends across the United States and assess urban ecosystem services and values, tree health, and risk from pests and disease.

- The Forest Service continues to advance knowledge of cities as socio-ecological systems. In FY 2014, Forest Service scientists published a special research synthesis in the journal *Ecology and Society*, presenting new findings on the vulnerability and sustainability of the city of San Juan, PR, and expanding current knowledge of tropical urban systems.

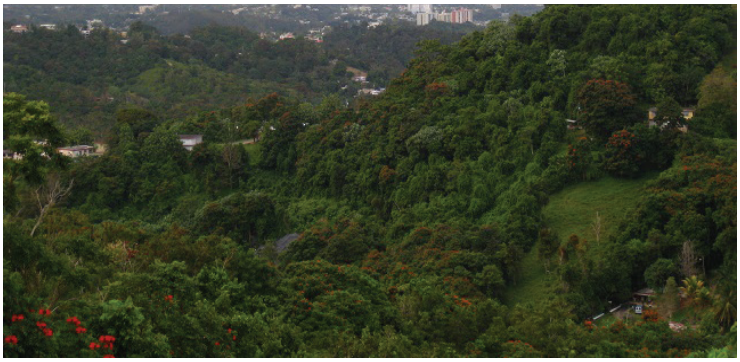
Cassandra Johnson Gaither, a natural resource social scientist, found that, in the South, socially vulnerable populations are less likely to have programs that help reduce the severity of wildfires than populations in more affluent communities living in high wildfire risk areas.

- Forest Service scientists developed the first process-based carbon dioxide life-cycle inventory to assess the effectiveness of municipal tree-planting campaigns in climate mitigation. Research methods were used to assess Million Trees LA, one of the Nation's largest tree-planting initiatives, and provide recommendations for ensuring that the initiative remains a net carbon sink.

- Forest Service urban ecology research efforts in New York City were featured in a *New York Times* article (12/2/2014) on the role of data in informing land management, climate change policy, and resilience planning.

Highly Dynamic Urban Forest in San Juan, PR

Between 2001 and 2010, the urban forest in the San Juan Watershed in Puerto Rico was highly dynamic. Nearly 50 percent of trees originally sampled in 2001 in several permanent plots across the watershed had been removed or had died. Growth of new trees exceeded mortality, however, and resulted in an average increase of 40 trees per acre. The urban forest had a mean diameter growth rate of 0.39 inches per year. Overall, growth of nonnative and invasive species was best correlated with human population density, whereas growth of native species was best correlated with tree density. Much of vegetation dynamics observed in the San Juan Watershed can be attributed to human activities.



The southern part of the San Juan Bay Estuary in Puerto Rico, a hilly area derived from volcanic soils, is less densely developed and has higher tree cover than other parts of the watershed. (Photo by Tom Brandeis, USDA Forest Service)

Managing Wood Decay in the Urban Forest

Arborists need tools to help identify patterns of wood decay as part of tree risk analysis and decisions regarding the proper care of urban and community trees. Forest Service scientists prepared a series of articles to introduce arborists to frequently encountered decay fungi and patterns of decay in common oak and riparian tree species.

Tree failure resulting in damage to a house in Kennebunkport, ME. (Photo courtesy of USDA Forest Service)

Trees in Los Angeles: Carbon Dioxide Sink or Source

Tree planting is considered to be among the most effective approaches to cooling urban environments and mitigating carbon dioxide emissions. The Los Angeles tree program, known as "City Plants," is one of several mayoral tree-planting initiatives launched in the largest U.S. cities. Altogether, the largest cities have pledged to plant nearly 20 million trees, in most cases, for climate protection. Research findings suggest that this tree-planting initiative, and possibly others, can be net carbon dioxide sinks, especially if trees are strategically located to reduce energy consumed for air-conditioning and heating. Forest Service scientists also found ample opportunities to further reduce emissions. Examples include selecting drought-tolerant trees and utilizing wood for wood products to generate electricity instead of for producing mulch.

Two members from the Los Angeles Conservation Corps plant a tree. The Los Angeles tree program, known as "City Plants," stressed creating jobs, particularly for underserved youth and young adults in Los Angeles. Through its partnership with the Los Angeles Conservation Corps, 208 young people earned their high school diplomas while working on the program. (Photo by Elizabeth Skrzat, City Plants)

Outdoor Recreation

National forests and grasslands offer the largest source of outdoor recreation opportunities in the United States. Forest Service scientists provide science and technology that recreation and wilderness managers can use to balance the demand by people for recreation and rejuvenation from the outdoors with the need to sustain healthy ecosystems.

Federal Outdoor Recreation Trends: Effects on Economic Opportunities

Outdoor recreation holds a significant place in American lives and culture. It inspires interest and appreciation of the natural world and contributes to the physical, mental, social, and spiritual health of individuals. Federal lands provide recreation opportunities and also generate positive economic effects for nearby communities. Visitors to Federal lands spend money in these communities, supporting local businesses that provide facilities, products, and services related to recreation. This business activity creates jobs and sustains incomes, broadens local tax bases, and helps diversify the economy of many rural areas. In 2012, Americans spent about $51 billion for recreation-related purchases in communities near Federal lands and waters managed by Federal Interagency Council on Outdoor Recreation (FICOR) agencies, supporting nearly 880,000 jobs nationwide.

The Forest Service National Center for Natural Resources Economics Research, a virtual center designed to respond to emerging natural resource economic issues of national significance, is assisting the FICOR in understanding the likely impact of future recreation trends on recreation-related economic opportunities.

Population growth will drive increases in both recreation participation and total days of participation. With a stable Federal land base of approximately 640 million acres, nearly all of which is available for public recreation, areas of greatest population growth will experience the most pressure. Rural communities and enterprises within and around Federal lands will see expanded opportunities with growth in demand through 2030 for all types of recreation activities.

The greatest increase in total days of use will occur in visits to developed sites for activities such as picnicking and visiting nature centers, viewing and photographing nature, hiking, and swimming.

Forest Service social scientist Linda Kruger works to enhance opportunities in the development of recreation and tourism and to identify meaningful ways to engage the public and generate an understanding of these activities and their role in community well-being. Her projects include studying the effects of climate change and social change on Alaska Native populations.

Expenditures for lodging; food in restaurants, bars, and grocery stores; and fuel account for the majority of recreation trip spending. Communities, however, may increase visitor spending by offering complementary attractions, guides, and other experiences to lengthen visitor stays and encourage return visits. Knowing that the clientele will be increasingly urban, older, and more ethnically diverse is key to designing experiences that attract participants. Attention to sustaining public lands as high-quality recreation destinations is also critical. Degraded resource quality, congestion, and development encroachment can be anticipated and mitigated by increasing investments in Federal lands to support recreational options for the public and economic opportunities for rural communities.

FICOR is made up of agencies whose missions or programs include providing outdoor recreation and conserving or managing natural and cultural resources. These agencies include the Bureau of Land Management, Bureau of Reclamation, Forest Service, National Oceanic and Atmospheric Administration, National Park Service, U.S. Army Corps of Engineers, and U.S. Fish and Wildlife Service.

Benefits and Losses of Wildfires on the San Jacinto Wilderness

Forest Service scientists discovered that recently burned landscapes are attractive to forest recreationalists. This information can help fire managers understand recreational use and strategically place existing resources to help protect high-value areas.

Results suggest that recreationists are attracted to sites with recent wildfires that can be viewed up close. Societal benefits from recreational activity increased for sites that were partially affected by different types of wildfires, with the greatest gains observed for the most recent wildfires. Wildfires that caused trail closures, however, created societal losses. Estimated total seasonal losses for complete closure of five trails, which excluded users from the land, ranged from $29,600 to $2.9 million.

James Trappe (Forest Service, emeritus scientist) and Turgut Keskin (Turkish entrepreneur interested in developing a commercial truffle industry in Turkey) enjoy the aroma of Tuber aestivum near Denizli, Turkey. (Photo by Michael Castellano, USDA Forest Service)

Forest Service Scientists Help Turkish Foresters Cultivate Truffle Species

Forest Service scientists provided training to Turkish Ministry of Forestry personnel in the importance of ectomycorrhizal fungi to forest productivity. They created a framework for assessing and monitoring ectomycorrhizal truffle diversity in Turkish forests in the hope of developing a commercial (culinary) truffle harvest in Turkey.

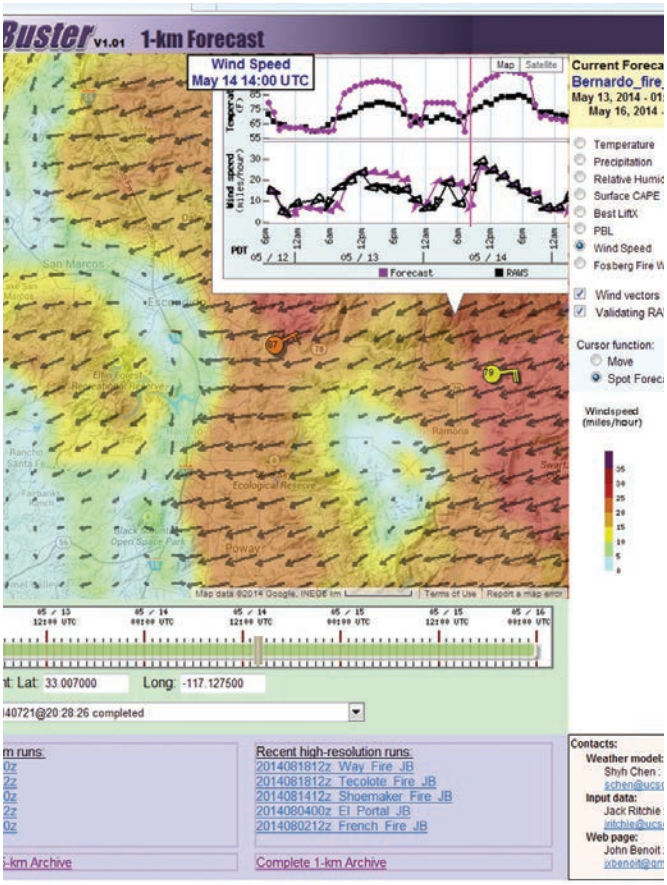
Scenic views from San Jacinto Wilderness, San Bernardino National Forest. (Photo by José J. Sánchez, USDA Forest Service)

Wildland Fire and Fuels

Each year, tens of thousands of wildland fires cover millions of acres across the United States, causing billions of dollars in damage. Forest Service scientists conduct cutting-edge work in wildland fire research and develop tools, methods, and applications to improve our understanding and management of fire, fuel, and smoke.

Firebusting Weather Forecasts

During fire incidents, detailed, site-specific, and timely weather projections are critical for firefighting efforts. Forest Service scientists developed an experimental system called FireBuster that can produce a forecast with a 3-mile resolution. A field forecaster can also request a more detailed (0.6-mile resolution) 72-hour forecast with only a few clicks on a Google map, and, then, retrieve the results through a Web interface. FireBuster provides firefighters with location-specific, detailed weather forecasts, including winds, and could help save lives and protect communities.



David Weise, a research forester, studies prescribed fire and how it can be used as a tool to manage U.S. forests and wildlands.

A screenshot of FireBuster 1-kilometer run results showing surface wind speed (in color) and wind vector forecast for the area around Bernardo Fire on August 13, 2014 (lower left of the map), about 5 miles south of Escondido, CA. The map shows the 38th hour forecasted weather validated at 7 p.m. Pacific Standard Time, August 14, 2014. Signature Santa Ana wind was from the east and modified by the terrain. The forecasted weather and wind were validated well against those corresponding Remote Automatic Weather Stations of San Pasqual (near the center of the map) and Goose Valley (right), respectively, at this particular hour, as well as during the entire 72-hour forecast. (Photo by John Benoit, USDA Forest Service)

Analyzing How To Increase Fireline Production Efficiency

Operational data on fireline—a strip of land cleared of flammable materials and dug down to mineral soil—production rates in general are lower than the rates identified by expert panel estimates. This study found the lower operational rates can be linked to excessive firefighter fatigue, safety considerations, and likely suboptimal managerial decisionmaking.

Economic costs of fighting the largest fires are increasing. (Photo courtesy of Georgia Forestry Commission)

Climate Regulates Sagebrush Recovery After Fire

Wildland fire plays a key role in shaping natural communities on semiarid landscapes around the world. The composition and structure of plant communities are often tied to specific patterns of fire frequency and size. Knowledge of fire characteristics compatible with sagebrush-dominated communities of the U.S. Intermountain West is critical for maintaining habitat crucial for sagebrush-dependent wildlife, such as greater sage grouse. In recent studies, Forest Service scientists investigated natural recovery of mountain big sagebrush for 36 fires in the Great Basin and Colorado Plateau ecoregions.

View of vegetative recovery 5 years after a fire on a Colorado Plateau site includes scattered mountain big sagebrush plants that grew from seeds that survived the fire. These young plants are just large enough to begin producing seeds. Plant density on this site is sufficient to support a prediction of full sagebrush recovery in 25 to 35 years after the fire. (Photo by Stanley G Kitchen, USDA Forest Service)

Examining Trade-Offs in Wildland Fire Management Decisions

Reducing or mitigating the negative effects of wildland fire is a major priority in communities all across the United States and must be addressed across agencies and jurisdictional boundaries. The National Cohesive Wildland Fire Management Strategy is a multiyear effort by Federal agencies working with States, tribal governments, and other interested public entities to develop an integrated and comprehensive plan to collaboratively reduce human and ecological losses from wildfire.

Wildland fire can have destructive ecological and social effects. (Photo courtesy of Georgia Forestry Commission)

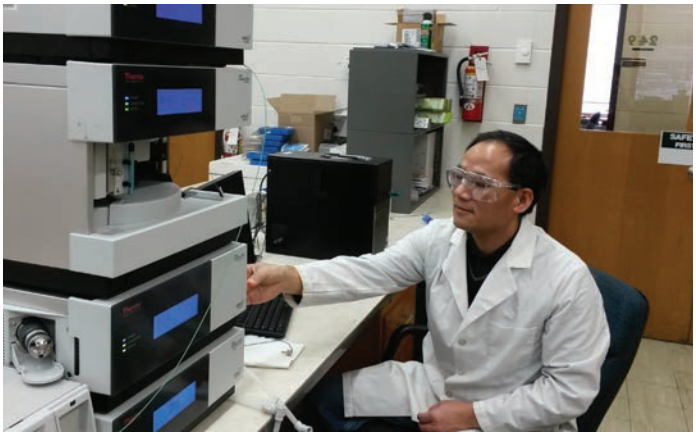
Forest Service Researchers Focus on Firefighter Safety

Wildland firefighters continue to be injured or killed in fire entrapments. Past entrapment data indicate that policy changes, improved work practices, and new technology can reduce entrapments. For the past 6 years, Forest Service scientists at the agency's Rocky Mountain Research Station have worked to develop new information on safety zones and escape routes that can help keep firefighters safe.

Firefighters exit area where safety zone sensors were deployed on a fire in Nevada in 2014. (Photo by Dan Jimenez, USDA Forest Service)

Forest Products

Led by the Forest Products Laboratory (FPL), the Forest Service identifies ways to innovatively use wood and fiber, contributing to the conservation and productivity of forest resources and leading to sustainability for forests, the economy, and quality of life. Among FPL's focus areas are advanced structures that use technology to change a building's affordability, durability, quality, energy use, and disaster resilience and that use nanotechnology that advances knowledge about the fundamental components of wood at atomic and molecular scales.



J.Y. Zhu, a research general engineer, developed a chemical process that can use a paper mill pulping digester to treat unusable wood pieces. These pieces are then converted to simple sugar and biofuel through bioconversion, a process using enzymes and microorganisms to carry out biochemical reactions with wood.

Cellulose Nano-Enabled Products: Applications and Volume Estimates

Cellulose nanomaterials are the next big (albeit, small) thing in wood. They can be combined in numerous ways to change the way many products work. FPL research identified potential end-product markets and provided estimates of the potential demand for wood-based cellulose nanomaterial. The greatest volume potential for use of cellulose nanomaterials is currently in paper and packaging applications. Other potentially high-volume cellulose nanomaterial uses are in the automotive, construction, personal care, and textile sectors.

Forest Service scientists Alan Rudie (left) and Richard Reiner stand with cellulose nanocrystals manufactured at the Forest Products Laboratory. (Photo by Steve Schmieding, USDA Forest Service)

A Smart Sponge Soaks Up Pollutants

The "smart sponge" is one of a number of applications under development for the tiny wood fibers known as cellulose nanofibrils (CNF). The fibers possess a number of unique properties including renewability, high surface areas, high aspect ratios, and excellent mechanical properties.

Forest Service scientists developed a series of CNF-based organic aerogels that may be used for a number of applications including superabsorbents, thermal insulation, polymer nanocomposites, and supercapacitors. As superabsorbents, these renewable resources-based aerogels may be used in environmental cleanup efforts after chemical or oil spills.

Cellulose nanofibril smart sponge absorbs oil that is floating on the top of the water. (Photo by Bryce Richter, University of Wisconsin)

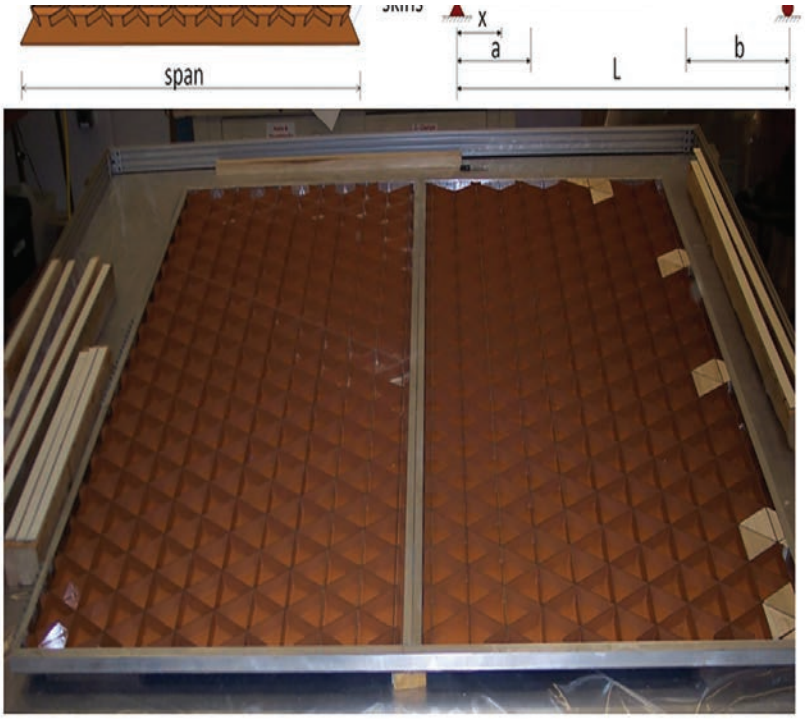
The Xylotron: A Field-Deployable Machine-Vision-Based Wood Identification System

The Xylotron is a machine-vision-based wood identification system that uses a custom-designed wood imaging device (Xyloscope), an image analysis, and statistical processing software run from a laptop/netbook. With the Xylotron, users can identify more than 150 species of wood more accurately than trained law enforcement personnel. The technology could help combat the global problem of illegal logging by empowering law enforcement agents to identify wood species in the field.

The Xylotron uses machine-visioning technology to identify wood species. (Photo by John Hermanson, USDA Forest Service)

3D Engineered Panels From Laminated Paper Composites Have Broad Potential

Forest Service researchers are studying the use of high-strength laminated paper composite material as a low-cost replacement for aluminum and synthetic fiber-based composite panels for a variety of applications. Using proper three-dimensional (3D) engineered placement and design, panels made from wood-based composite materials show high-strength potential, including water and limited fire resistance. The researchers are studying the core geometry to improve performance through optimized multiaxis orientation and material alignment.



Tactical shelter door made using three-dimensional engineered fiberboard made from laminated paper. (Photo by John Hunt, USDA Forest Service)

Invasive Species

Invasive species have significantly impacted U.S. ecosystems and cost millions of dollars to prevent, detect, and control. Forest Service R&D provides the scientific information, tools, and methods that regulators, managers, and the public need to address invasive species.

Some accomplishments follow—

- Forest Service scientists observed that soils under the invasive plant Chinese privet, which has invaded 80 percent of available riparian floodplain forest habitat in Southeastern forests, had higher numbers of nonnative invasive earthworms than soils without the privet. The most abundant nonnative earthworm species were reduced and promoted the recovery of a North American native earthworm species 5 years after the removal of the Chinese privet. After removal of Chinese privet, the soil acidity level increased nearly to that of soils without privet invasion. The acidity changes may favor the native species. Thus, removal of one invasive species may result in the control of another, short circuiting the invasion meltdown that the expansion of Chinese privet causes.

- Forest Service scientists and their colleagues found up to a 52-percent drop in the infestation rate of wood packaging material associated with international imports on crates and pallets entering the United States after the 2005 implementation of International Standards for Phytosanitary Measures No. 15 (ISPM 15). The ISPM 15 stipulates how wood packaging material should be treated before use in packing goods for export. Many invasive bark- and wood-infesting insects, such as the Asian longhorned beetle and the emerald ash borer, likely entered the United States as stowaways in untreated wood packaging from foreign ports. The study shows that regulatory solutions such as phytosanitary standards can have a major impact on the biological security of the United States.

- In Hawaii, relative dominance of native and nonnative tree species influences patterns of forest carbon and biodiversity. Forest Service scientists determined aboveground carbon in wet lowland forests of Hawaii by collecting Light Detection and Ranging, or LiDAR, data and developed relationships between LiDAR metrics and field-based estimates of forest carbon. This approach allowed for the inventory of entire forest regions. Forest carbon mass increased with lava flow age but differed between native and nonnative forest stands due to the presence of the nonnative nitrogen-fixing trees. After 500 years of primary succession, both forest types averaged the same carbon stock, although nonnative forests achieved those levels in only 75 years. Given the large areas of early successional native forest on young lava flows, further spread of nonnative nitrogen-fixing trees may increase carbon storage, but it would reduce the invaluable contribution of Hawaii's native ecosystems to global biodiversity.

A Suite of Introduced and Native Enemies Reduces Populations of the Emerald Ash Borer

Originally from Asia, the emerald ash borer (EAB) is an invasive wood-boring beetle that attacks and kills ash trees in the United States. The long-term and sustainable management of this destructive pest involves the release of specialized insect natural enemies from Asia into our EAB-infested forests. At study sites in Michigan forests, Forest Service scientists and their research partners have found a suite of introduced and native natural enemies working in tandem to reduce populations of EAB.

An emerald ash borer larva feeding under the bark of an ash tree. (Photo by Leah Bauer, USDA Forest Service)

Biocontrol Agent for the Invasive Ailanthus Tree To Be Tested

Forest Service scientists are studying a North American fungus that selectively kills Ailanthus trees, a nonnative invasive tree from Asia difficult to control with herbicides or cutting. Test sites were selected in Ohio forests and trials will begin in the spring of 2015 to test the effectiveness of a soil-borne fungus on controlling Ailanthus.

Ailanthus tree inoculated with wilt fungus. Note drooping and wilting foliage. (Photo by Joanne Rebbeck, USDA Forest Service)

Female Asian Longhorned Beetles Lure Mates With a Trail of Sex Pheromone

The Asian longhorned beetle is an invasive pest attacking about 25 tree species in the United States. Forest Service researchers and partners have found that female Asian longhorned beetles lure males to their locations by laying down a sex-specific pheromone trail on the surfaces of trees. This finding could lead to the development of a tool to manage this invasive pest.

Male Asian longhorned beetle choosing the branch with the sex-specific pheromone trail. (Photo by Melody Keena, USDA Forest Service)

Wood Heat Treatment Reduces the Risk of Spreading Thousand Cankers Disease

Black walnut, one of the most valuable hardwood timber species in the United States, is being killed by "thousand cankers disease," which is caused by a tiny bark beetle and an associated fungus. The disease organisms can spread to new areas through the movement of infested walnut logs, firewood, or other unprocessed wood products that are commonly transported for commercial trade. Forest Service scientists and their research partners developed a heat treatment schedule that eliminates the bark beetle and the fungus from infested walnut logs to help slow the spread of thousand cankers disease in the United States and abroad.

Forest Service entomologists Bud Mayfield (left) and Paul Merten (right) examine the bark of a black walnut branch for evidence of the walnut twig beetle, the vector of the fungus that causes thousand cankers disease. (Photo courtesy of USDA Forest Service)

Wildlife and Fish

Forest Service research provides managers and decisionmakers with the tools and knowledge necessary to help protect, enhance, and restore fish and wildlife habitats and minimize the effects of disturbances such as fire, urbanization, disease, and climate change.

Using New Technology To Track a Rare Songbird During Migration

The cerulean warbler is a tiny forest bird in big trouble. To better understand where these birds go when they migrate out of their Appalachian breeding grounds, Forest Service scientists and their university partners have begun using light detecting geolocators: tiny backpacks that record the birds' locations. When recovered next spring, these geolocators will reveal where the birds traveled, which will help inform where to focus conservation efforts.

A male cerulean warbler gets fitted with a light-detecting geolocator, which will record its location as the bird migrates to its wintering grounds. (Photo by Nathan Weyandt, USDA Forest Service)

Resilience of Sagebrush Ecosystems Used for Improving Sage-Grouse Habitat

New research from the Forest Service's Rocky Mountain Research Station on sagebrush ecosystems is being put to use to benefit greater sage-grouse habitat on Federal lands across the Intermountain West. An interagency effort initiated by the Western Association of Fish & Wildlife Agencies, led by the Forest Service, developed a strategy for decreasing the impacts of invasive grasses and wildland fire on sage-grouse habitat.

Roy Lopez, a wildlife biologist, holds a bald eagle while studying wintering eagles near Morman Lake, Arizona. The study revealed that a spike in the number of wintering bald eagles one year was due to fathead minnows frozen into the ice during low water levels. Instead of 10 to 15 wintering birds, this food source caused a weekly high of about 120 eagles.

In August 2014, the Bureau of Land Management issued guidance through an instructional memorandum to its offices across California, Idaho, Nevada, Oregon, and Utah to begin implementing the report's findings.

Greater sage-grouse (*Centrocercus urophasianus*). (Photo by Charlotte Ganskopp, USDA Agricultural Research Service)

Bird Monitoring in the Western Great Lakes National Forests Shows Stabilized Breeding Bird Populations

The results from 20 years of forest bird monitoring in four national forests in Minnesota and Wisconsin show positive trends in breeding bird population stability. A new report by Forest Service scientists and their research partners represents the most comprehensive volume of quantitative information ever compiled on the trends, habitat use, and community assemblages of breeding forest birds of the western Great Lakes region.

Study findings showed the ovenbird (*Seiurus aurocapilla*) has had significantly increasing numbers since 1995 in the Chippewa, Superior, and Chequamegon-Nicolet National Forests. In addition, the ovenbird and red-eyed vireo (Vireo olivaceus) were the two most abundantly recorded species in the Chippewa and Chequamegon-Nicolet National Forests. Common species such as the ovenbird tended to occur in many forest cover types, but they most commonly occurred in upland hardwood forests. (Photo by Jon Swanson)

Elusive Carolina Northern Flying Squirrels in Red Spruce Forests Face Survival Challenges

The endangered Carolina northern flying squirrel is a secretive, nocturnal species and not much is known about its behavior and ecology. Forest Service researchers were part of a team that studied habitat preferences of this species. Study results showed that red spruce is vital to assuring suitable habitat for the Carolina northern flying squirrel and protecting it from competition and the parasites associated with the more aggressive southern flying squirrel.

A radio-collared Carolina northern flying squirrel. (Photo by Corrine A. Diggins, Virginia Polytechnic Institute and State University)

Tracking the Decline of Bats in North America

Although it is well known that bat populations in North America are declining rapidly from white-nose syndrome (WNS), wind energy development, and other causes, the full extent of the decline has only been estimated. The North American Bat Monitoring Program (NABat) provides the statistical and logistical architecture for coordinated bat monitoring to support local, regional, and rangewide inferences about trends in bat distributions and abundances in response to WNS, climate change, wind energy development, and habitat loss. Results from this program will provide managers and policymakers with the information they need about bat population trends to effectively manage bat populations, detect early warning signs of population declines, and estimate extinction risk.

A little brown bat is infected with white-nose syndrome. (Photo by Nancy Heaslip, New York Department of Environmental Conservation)

Terrestrial Mollusks Respond to Logging in Riparian Areas

Little is known about the biology and response to environmental change of native, terrestrial mollusks (i.e., slugs and snails) in the Pacific Northwest. Because of mollusk affinities to moist environments, the effect of human-caused habitat alteration from logging is assumed to be detrimental but is largely unknown. This study illustrates that site differences can affect mollusk community structure and influence resiliency to disturbances such as logging. This research contributes to our understanding of a little-studied but important component of Pacific Northwest forest biodiversity.

The Malone jumping slug (*Hemphillia malonei*) is one of seven species of jumping slugs found in the Pacific Northwest. (Photo by Robin Malone, USDA Forest Service)

Performance and Future Outlook

FYs 2012–2014 Performance

Forest Service R&D reports a variety of metrics at periodic times of the year to assist internal managers and external partners in decisionmaking and to meet the requirements of Congress, the Office of Management and Budget, and USDA on performance accountability (table 1).

Accomplishment reporting is critical to achieving Forest Service goals and objectives and to supporting performance-driven management and budget decisions. To be effective, data must be accurate and reliable. They must also meet the Government standards for quality and accountability.

Table 1. Forest Service R&D Performance in Key Metrics

Performance Measure	FY 2012	FY 2013	FY 2014
Customer satisfaction index score	79	79	79
Articles published in journals and other publications	3,699	3,460	2,474
New inventions disclosed	23	25	19
Patent applications filed	8	7	10
Patents granted	3	4	4
Invasive species tools developed, delivered, and used	169	193	168
Percent of States for which FIA data are current and accessible	92%	96%	98%

FIA = Forest Inventory and Analysis. FY = fiscal year. R&D = Research and Development.

Future Outlook

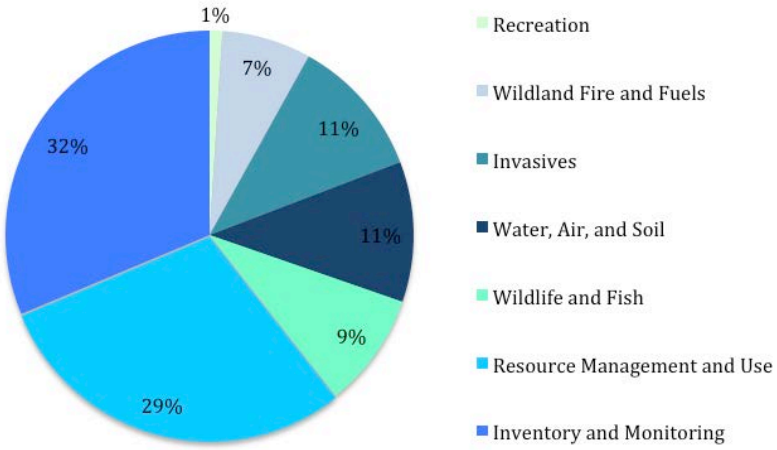
The FY 2016 President's Budget proposes $291,982,000 for forest and rangeland research, a decrease of $4,018,000 from the FY 2015 enacted level. The request provides $83 million for the FIA program.

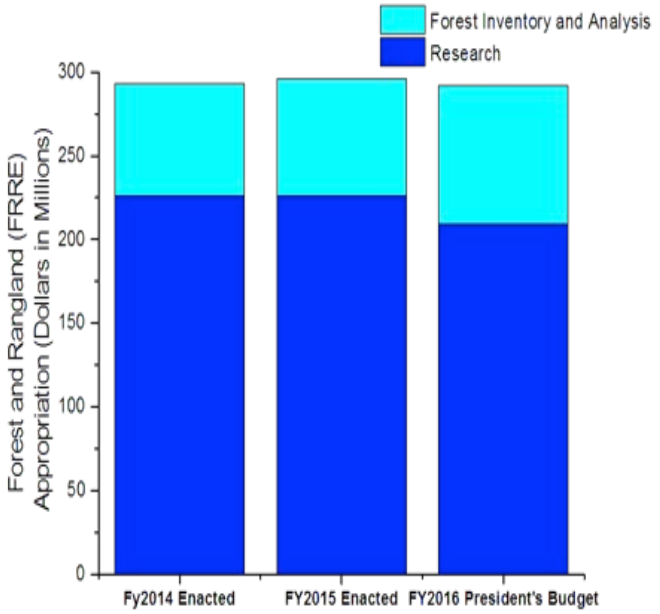
The Forest Service R&D program structure has two integrated components: priority research areas and strategic program areas. To address emerging needs and agency priorities, Forest Service R&D funds the priority research areas from across the strategic program areas (table 2). The FY 2016 President's Budget will continue to focus on key research in these two components.

Table 2. Enacted and Proposed Funding for R&D Strategic Program Areas

R&D Strategic Program Areas	FY 2014 Enacted	FY 2015 Enacted	FY 2016 President's Budget
	(dollars in thousands)		
Wildland Fire and Fuels	22,160	22,160	20,524
Invasive Species	35,106	35,106	32,451
Recreation	4,423	4,423	4,111
Resource Management and Use	93,382	93,382	86,249
Water, Air, and Soil	35,389	35,389	32,730
Wildlife and Fish	27,126	27,126	25,076
Inventory and Monitoring	75,217	78,412	90,841
Total	292,805	296,000	291,982

FY = fiscal year. R&D = Research and Development.





Funding Source	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Pres. Budget
	----------Dollars in Millions----------		
Research	$226	$226	$209
FIA	$67	$70	$83
Total FRRE	$293	$296	$292
Other Services			
National Fire Plan	$20	$20	$20
Joint Fire Science Program	$7	$7	$7
Total	$320	$323	$319

FIA = Forest Inventory and Analysis. FRRE = Forest and Rangeland Research. FY = fiscal year.
R&D = Research and Development.

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