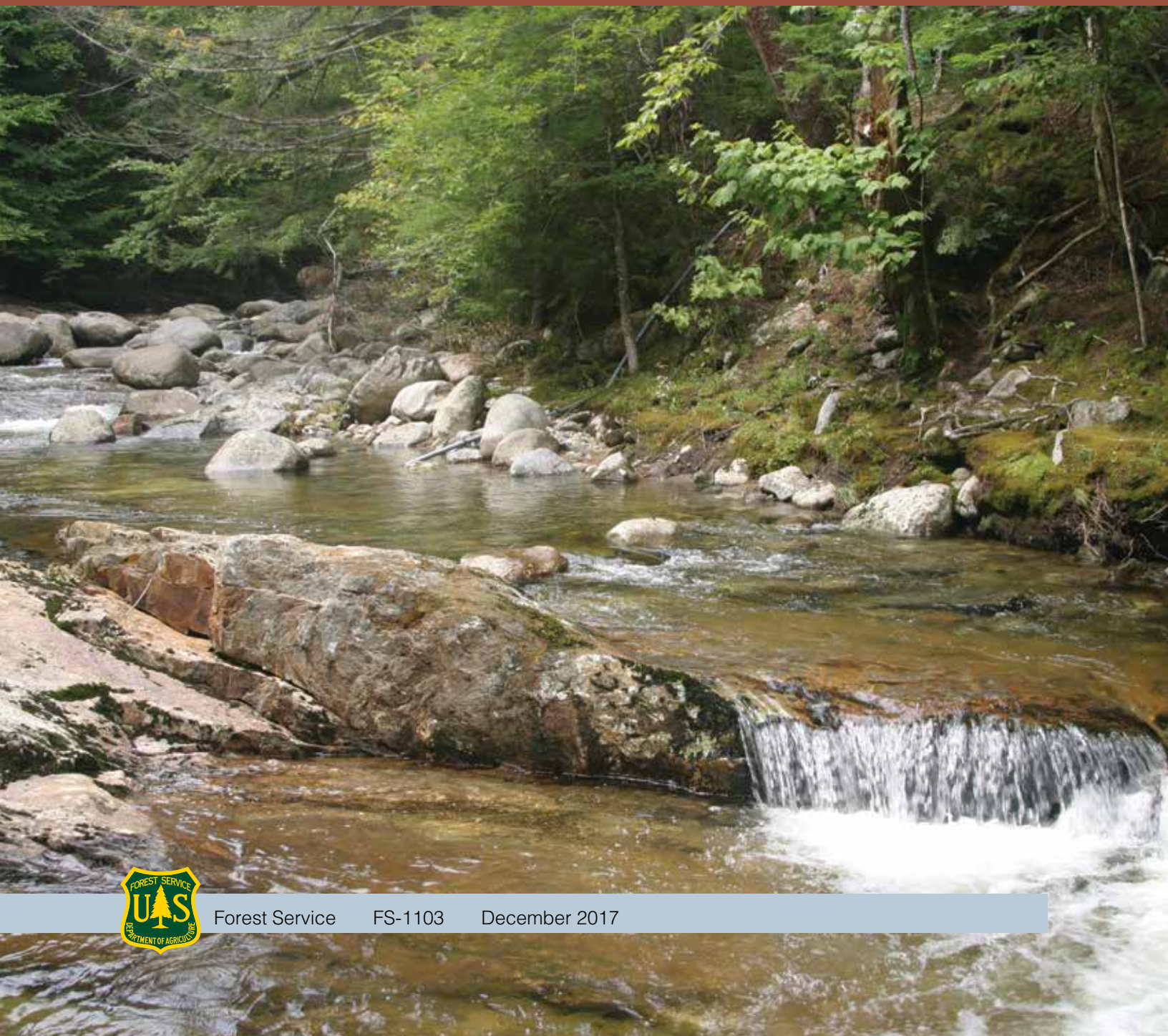




United States Department of Agriculture

Forest Service Research and Development Performance and Accountability Report

Fiscal Year 2016



Forest Service FS-1103 December 2017

The Research and Development (R&D) mission of the Forest Service, an agency of the U.S. Department of Agriculture (USDA), 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.



United States Department of Agriculture

Forest Service Research and Development Performance and Accountability Report

Fiscal Year 2016

Cover page photo caption: A summer view of Hubbard Brook at the point where it leaves the Hubbard Brook Experimental Forest. Forests are a primary source of clean, reliable water supply to many of our Nation's downstream towns and cities. Photo courtesy of Scott W. Bailey, USDA Forest Service.





The Research and Development (R&D) mission of the Forest Service, an agency of the U.S. Department of Agriculture (USDA), 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.



ABOUT THIS REPORT

The Government Performance and Results Act of 1993 requires all Federal agencies to engage in a strategic planning process that aligns resources with results and improves the accountability of all Government activities to the American people.

This process focuses on results and includes the development and implementation of a 5-year strategic plan. Annual reporting identifies specific, measurable targets for performance at the beginning of each fiscal year and a year-end assessment of the success of these endeavors.

The *Forest Service Research and Development Performance and Accountability Report Fiscal Year 2016* is the year-end progress report of the USDA Forest Service, Research and Development (R&D) Deputy Area. The data that Forest Service R&D used to measure performance are collected using a standardized methodology that conforms to generally recognized principles for reporting.

This report describes the Forest Service R&D organization, explains how it has applied the public's investments, and provides an accounting of budgets and accomplishments. It aims to help policymakers make informed decisions and presents an overview for all Americans interested in the workings of their Government and R&D's ability to manage for results in delivering its information, technology, and applications.





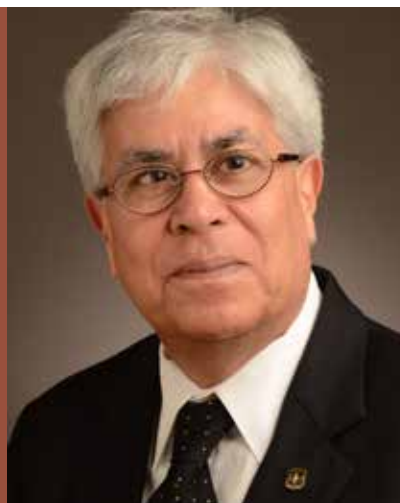
CONTENTS

3	About This Report
6	Message From the Deputy Chief
8	The R&D Mission
8	Organizational Structure
9	The Washington Office
11	Research Locations
13	The Foundations of Forest Service R&D
14	Workforce
15	Budget and Finance
17	Forest Service Strategic Plan
18	Strategic Program Areas
20	Research Accomplishments That Support Agency Goals and Objectives
30	Priority Research Areas
32	Partnerships
33	Measuring Forest Service R&D Performance
35	Workplace Improvements
36	National Accomplishments

MESSAGE FROM THE DEPUTY CHIEF OF RESEARCH AND DEVELOPMENT

Carlos Rodriguez-Franco

Deputy Chief of Research and Development



I am pleased to present the U.S. Department of Agriculture Forest Service Research and Development (R&D) Deputy Area's *Fiscal Year 2016 Performance and Accountability Report (PAR)*. The PAR provides an overview of R&D's mission, internal structure, accomplishments, and strategies implemented to achieve and align with the agency's goals.

The PAR also details how R&D's performance and financial information is handled and managed to ensure accuracy and completeness; it presents key budget and financial information to Congress and other external interested parties for purposes of transparency and accountability; it serves as a year-end progress report to inform the American people of the return on their investments; and it identifies areas of anticipated change and future focus.

Sound scientific information is needed to address threats that impact our forests, grasslands, and urban environments—threats such as invasive pests, pollution, fire, water shortages, and population pressures. A science-based agency, Forest Service R&D provides scientific information

to mitigate these threats and to support the core mission of the Forest Service: (1) developing solutions to complex problems and employing science-based options and tools that help land managers restore and maintain healthy forests and grasslands; (2) making available multiple environmental and social benefits, such as clean air, clean and abundant water, and a wide range of ecosystem services; (3) providing an array of recreational opportunities; and (4) developing innovative ways to protect, use, enhance, and sustain our Nation's forests for the benefit of all.

Fiscal year 2016 was a challenge for R&D. Fire suppression costs reduced the Forest Service base budget, including R&D and other deputy areas. Forest Service budgets allocated to fire suppression have been increasing, in part due to climate change and urban expansion.

Forest Service R&D supports the Forest Service mission of *sustaining the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations* through the work of

dedicated scientists and technical staffs. R&D is recognized worldwide for its contributions to basic scientific knowledge and cutting-edge applications. Forest Service R&D also offers long-term, established research projects; a committed land base (experimental forests and ranges, watersheds, grasslands, demonstration areas, and research natural areas); ties to land managers; regional, national, and global perspectives; and a public service focus on questions of public significance.

I hope you read this report and visit our web page, where you will find 48,000 publications with detailed information about our scientific findings.

A handwritten signature in black ink that reads "Carlos Rodriguez Franco". The script is fluid and cursive, with the first name "Carlos" being the most prominent.

Carlos Rodriguez-Franco

Deputy Chief of Research and Development

THE R&D MISSION

The Research and Development (R&D) Deputy Area's mission flows directly from the Department and agency's strategic goals, objectives, and values. R&D's mission is to conduct 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.

Forest Service R&D values a dynamic and diverse workforce and is recognized as one of the premier natural resources research organizations in the world. We strive to be highly respected and influential advocates for innovative, highly valued science programs that inform sound natural resource management decisions, strengthen policymaking, and enable the Forest Service to fulfill its motto of "Caring for the land and serving people."

ORGANIZATIONAL STRUCTURE

The R&D mission area has been a vital part of the Forest Service since the agency's inception in 1905. The organization consists of five research stations: the Forest Products Laboratory (FPL) in Madison, WI; the International Institute of Tropical Forestry (IITF) in Puerto Rico; and 81 experimental forests and ranges. Forest Service R&D interacts with national forests in nine regions and with the State and Private Forest (S&PF) Deputy Area throughout the United States. Forest Service R&D is also allied with agencies in the USDA Research, Education, and Economics mission area, including the Agricultural Research Service (ARS), National Institute of Food and Agriculture, National Agricultural Statistics Service, and ARS's National Agricultural Library. Forest Service R&D also partners with other Federal agencies, nongovernmental organizations, universities, and the private sector.

THE WASHINGTON OFFICE

In 2014, Washington Office (WO) R&D aligned its structure to maximize performance and efficiency, produce tangible results that add public value, and respond to increased demand for scientific expertise and anticipated shifts in budget, workload, and capacity. Five staff groups are structured to ensure scientific and programmatic consistency and synergy between the research stations and national headquarters, provide science-based leadership in agency policy decision making, and provide strategic leadership and evaluation across broad program areas. This structure also helps to ensure timely and effective coordination and cooperation with other deputy areas within the Forest Service; with other USDA and Federal agencies, the Office of Management and Budget, and Congress; and with key non-Federal clients and stakeholders. By disseminating relevant research information and new technologies, this structure also helps headquarters make science-based policy and management decisions; ensures the consistent application of standards and procedures; and builds support for continued investments in research programs, facilities, and employees.

The **Inventory, Monitoring, & Assessment Research** (IMAR) staff has leadership responsibility in the R&D mission area for four broad lines of inquiry: (1) leading the Forest Inventory and Analysis (FIA) program and delivering it through using five research stations and partners inside and outside the Forest Service; (2) assessing cutting-edge developments in monitoring, remote sensing, and geospatial analysis and helping set priorities for further work within the R&D mission area to capitalize on them; (3) conducting assessments of renewable resource conditions—including analyses of current conditions, recent trends, and projected future conditions—and setting priorities for techniques research on assessment and projection methodologies; and (4) expanding and accelerating the use of decision-support systems and tools for land management planning. The prime objective for IMAR staff across these four lines of inquiry is to build through synthesis and integration of field scientists' findings a solid scientific foundation for natural resource management and policymaking at multiple spatial scales in boreal, temperate, and tropical forest ecosystems. The

IMAR staff also has leadership responsibility for the R&D mission area for setting policies for quality assurance and quality control (QA/QC) strategies and tactics, including statistical and peer reviews of R&D study plans, manuscripts, and reports, and conducting oversight to validate ongoing research station activities in these areas and assure national consistency in QA/QC strategies and tactics.

The **Knowledge Management and Communications** (KMC) staff manages information flowing into, out from, and within the R&D mission area. The objectives are to: (1) build broader awareness of current research and potential future research areas; (2) develop messages for deliberate, focused outreach to clients inside and outside the agency; and (3) strategically improve awareness, appreciation, and use of scientific knowledge in forming opinions and making management and policy decisions. The KMC staff also defines, develops, and maintains the national information architecture and content of databases essential to managing the strategic information flow and messaging about R&D.

The **Landscape Restoration and Ecosystem Services Research** (LRESR) staff has leadership responsibility in the R&D mission area for five broad lines of inquiry: (1) providing renewable natural resource managers and policymakers with economic evaluations and decision tools for management and policy options that promote healthy, resilient watershed conditions and wildlife and fish habitats; (2) 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; (3) exploring how settings with trees all along the urban-to-wildland gradient create values for people—whether neighborhood residents or recreation visitors—and how to practice more effective stewardship to enhance and sustain these values; (4) creating a 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; and (5) 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 LRESR staff members across these five lines of inquiry is to build through synthesis and advocacy of field scientists' findings a solid scientific foundation for natural resource management and policymaking at multiple spatial scales in boreal, temperate, and tropical forest ecosystems.

The **Policy Analysis** staff provides the Forest Service Chief and staff with timely, objective, and high-quality analyses of agency policies, programs, and practices.

The **Sustainable Forest Management Research (SFMR)** staff has leadership responsibility in the R&D mission area for three broad lines of inquiry: (1) advancing understanding about the interactions between stressors, threats, and

disturbances and the health, productivity, and sustainability of forests and rangelands; (2) assessing changes and risks to the biological diversity, health, productivity, and sustainability of forest and rangeland-dependent species; and (3) creating restoration strategies and management options for public and private forests, rangelands, and agroforestry lands. The prime objective for the SFMR staff members across these three lines of inquiry is to build through syntheses and advocacy of field scientists' findings a solid scientific foundation for natural resource management and policymaking at multiple spatial scales in boreal, grasslands, temperate, and tropical forest ecosystems.

RESEARCH LOCATIONS

Forest Service R&D is a world leader in innovative science for sustaining global forest resources for future generations. Research findings and products benefit forest and rangeland managers and everyone who uses goods or services from forests. Forest Service R&D operates five research stations that encompass all 50 States, a national Forest Products Laboratory in Madison, WI, and the International Institute of Tropical Forestry in Puerto Rico (fig. 1). Approximately 500 scientists and hundreds of technical and support personnel work at 67 field sites throughout the United States, Puerto Rico, and the U.S. affiliated Trust Territories and nations of the Pacific. Forest Service R&D maintains 81 experimental forests and ranges, which support most of the agency's long-term research, across the Nation.

The **Forest Products Laboratory (FPL)**, headquartered in Madison, WI, is concerned with the long-term health of

the Nation's forests and how the Nation depends on sound conservation practices, including wood and wood byproduct utilization. FPL uses science and technology to conserve and extend the Nation's forest resources and to develop innovative wood-related products. FPL's mission is to promote healthy forests and forest-based economics through the efficient, sustainable use of wood resources.

The **International Institute of Tropical Forestry (IITF)**, headquartered in Piedras, PR, has one work unit. The mission of this unit is to generate and disseminate scientific information in support of the sustainable use of tropical forests. The IITF accomplishes its mission through the development and dissemination of information on the use of forest resources, conservation of primary and secondary forests, rehabilitation of degraded lands, and management of wildlife and watersheds.

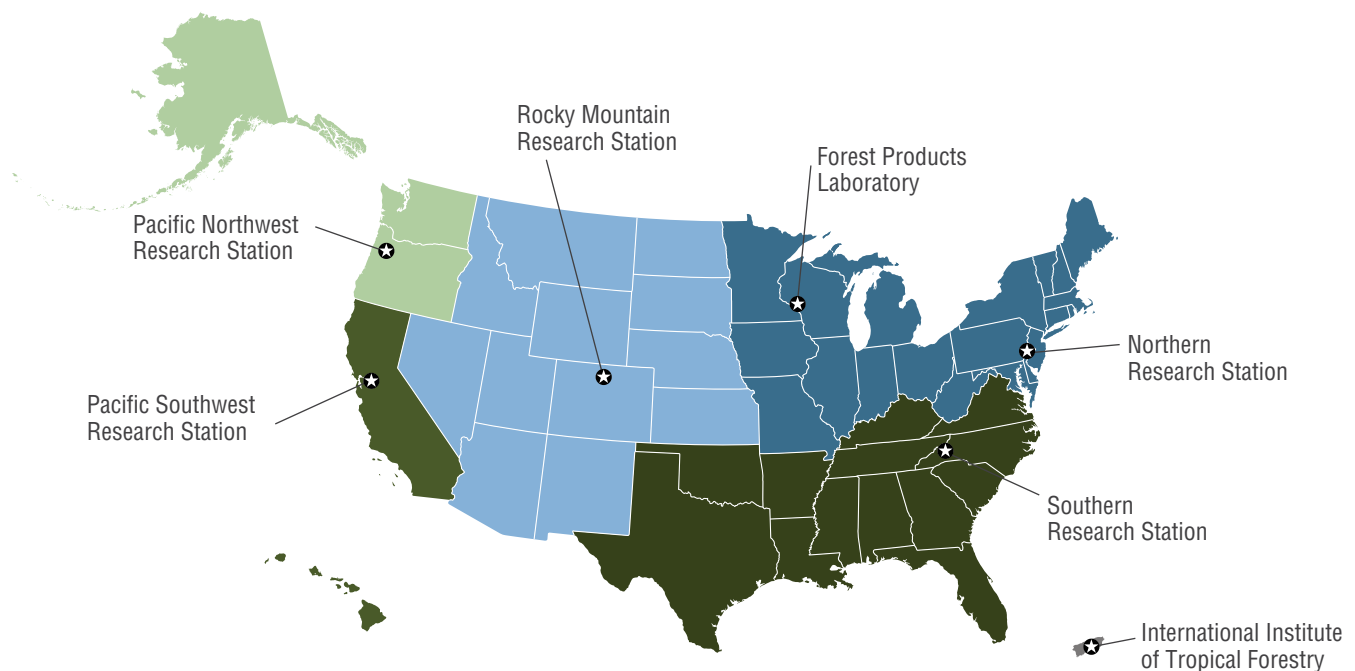


Figure 1. Locations of Research and Development's research stations, Forest Products Laboratory, and International Institute of Tropical Forestry.

The **Northern Research Station (NRS)**, headquartered in Newtown Square, PA, has research and development programs across 20 States in the Midwest and Northeast (Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, and Wisconsin). The station's research products and technologies provide the knowledge and tools to protect people and forest landscapes from the threat of undesirable disturbances, improve the quality of life in urban areas through natural resources stewardship, maintain and enhance forest productivity and benefits, and increase the production of clean water and air for a growing human population.

The **Pacific Northwest Research (PNW) Station**, headquartered in Portland, OR, maintains research and development programs in three States (Alaska, Oregon, and Washington) and provides scientific information to land managers, policymakers, and citizens. Like the other stations, its mission is to generate and communicate scientific knowledge that helps people understand and make informed choices about human behaviors and attitudes, natural resources, and the environment.

The **Pacific Southwest Research (PSW) Station**, headquartered in Albany, CA, conducts research, development, and application programs in California, Hawaii, and the U.S.-affiliated Trust Territories and nations of the Pacific. The PSW's primary work occurs in California (the most populous State, with the eighth largest economy in the world) and Hawaii (a strategic location in the Pacific Rim economies and tourism industry). The station develops and delivers science-based information, technologies, understanding, and applications to help people make

well-informed decisions about natural resource management, conservation, and environmental protection.

The **Rocky Mountain Research Station (RMRS)**, headquartered in Fort Collins, CO, conducts research across 12 States in the Interior West (Arizona, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, Utah, and Wyoming). Research at the RMRS is organized into seven science programs and a science application program that oversees two Research, Development, and Application units. The RMRS employs more than 400 professional, technical, and administrative personnel and 95 research scientists. These scientists and professionals, in collaboration with a variety of Federal, State, and university partners, develop high-quality scientific information responsive to land management and natural resource policy issues related to water supply, fire suppression and use, invasive species, wildlife and fish, climate change impacts, forest products use, human relationships to the land, and forest and grassland ecosystem restoration.

The **Southern Research Station (SRS)**, headquartered in Asheville, NC, conducts research programs across 13 States (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia). The SRS mission is to create the science and technology needed to sustain and enhance southern forest ecosystems and the benefits they provide to the public. The SRS has 15 work units grouped under 5 science areas that clearly define core strengths: (1) threats to forest health; (2) forest ecosystem restoration and management; (3) forest values, uses, and policies; (4) forest watershed science; and (5) forest inventory and monitoring.

THE FOUNDATION OF FOREST SERVICE R&D

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 ranges and (2) the FIA program, a national annual census of the Nation's forests.

Experimental Forests and Rangelands

The Experimental Forests and Rangelands (EFR) program provides the venue for long-term research in which Forest Service R&D scientists can address regional- to continental-scale environmental change issues in rural and urban areas. The 81 experimental forests and ranges comprise lands dedicated to research that have been authorized by Congress and designated by the Chiefs of the Forest Service during the past 100 years.

The EFR network, which has developed progressively since its inception in 1908, provides study sites for examining a wide variety of ecological questions that are specifically designed to address contemporary management challenges. Many of these sites are more than 50 years old and support research in all the major forest and rangeland vegetation types and geographical areas of the continental United States.

The EFRs are considered living laboratories, where Forest Service R&D can provide demonstrations of research project outcomes and results to cooperators and stakeholders. They represent some of the few places where ecological research can be maintained over the long term, and they perpetuate experimental studies far beyond the term of any individual scientist's career.

Forest Inventory and Analysis

The Forest Inventory and Analysis (FIA) program, a congressionally mandated census of the resources of U.S. forests, is conducted in partnership with the State foresters and S&PF. The program, which operates out of NRS, PNW, RMRS, and SRS, is coordinated nationally from the Washington Office. The FIA program assesses and reports on the status and trends in tree species by harvest, wood production and utilization, and forest land ownership. The FIA assessments extend to the Trust Territories and Puerto Rico and include reports on changes in carbon budgets and forest health. R&D manages the program in cooperation with a variety of partners, including State forestry agencies and private landowners, who grant access to their lands for data collection.

WORKFORCE

In fiscal year (FY) 2016, Forest Service R&D had 1,831 full-time employees, or FTEs, including research scientists, biological and forestry technicians, statisticians, and administrative and technical support staff (table 1). However, the number of R&D scientists has declined 19 percent during the past 10 years. Forest Service R&D hiring programs, such as the Scientist Recruitment Initiative, have been successful

in attracting entry-level scientists who will be positioned to research the current environmental and social issues facing the Nation's forests and grasslands. After completing their doctoral degrees, the students in the program will fill permanent scientist positions identified by program, research area, workforce, and diversity needs.

Table 1. Number of research scientists from fiscal years 2012–2016.

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
R&D FTEs	2,052	1,933	1,861	1,848	1,831
Research scientists	515	~500	~500	500	500

FTEs = full-time employees. FY = fiscal year. R&D = Research and Development.

BUDGET AND FINANCE

Forest Service R&D focuses its resources on the agency's mission, the priorities identified in the current agency strategic plan, direction from Congress, and priorities from the Executive Branch. The base Forest Service R&D mission area is formulated using input from the research stations, including FPL and IITF, which prioritize efforts needed to address the nature and magnitude of current and anticipated future resource problems and information requirements of resource managers. Station directors communicate frequently with users of research products and technologies to ensure they consider local, State, and regional resource issues. The directors then request budget levels that best serve the science and technology needs of their clients, including other Forest Service deputy areas. These field requests are reviewed, coordinated with strategic priorities, and merged into a national research

program. Funds to research stations, FPL, and IITF (fig. 2) are allocated to support the priorities and needs aggregated into R&D's seven Strategic Program Areas (see page 18). Forest Service R&D places a high priority on accountability and is committed to making the best use of taxpayers' dollars. Financial accounting is consolidated at the agency level.

In FY 2016, Forest Service R&D was appropriated \$291 million, a 1.7-percent decrease from FY 2015. This appropriated amount includes \$75 million for FIA (fig. 3) and \$6.3 million from the facility maintenance fund. In addition, Forest Service R&D received \$19.8 million for the National Fire Plan and \$6.9 million for the Joint Fire Science Program (table 2). The total funding to R&D represents 5.1 percent of the FY 2016 Forest Service appropriation (fig. 4).

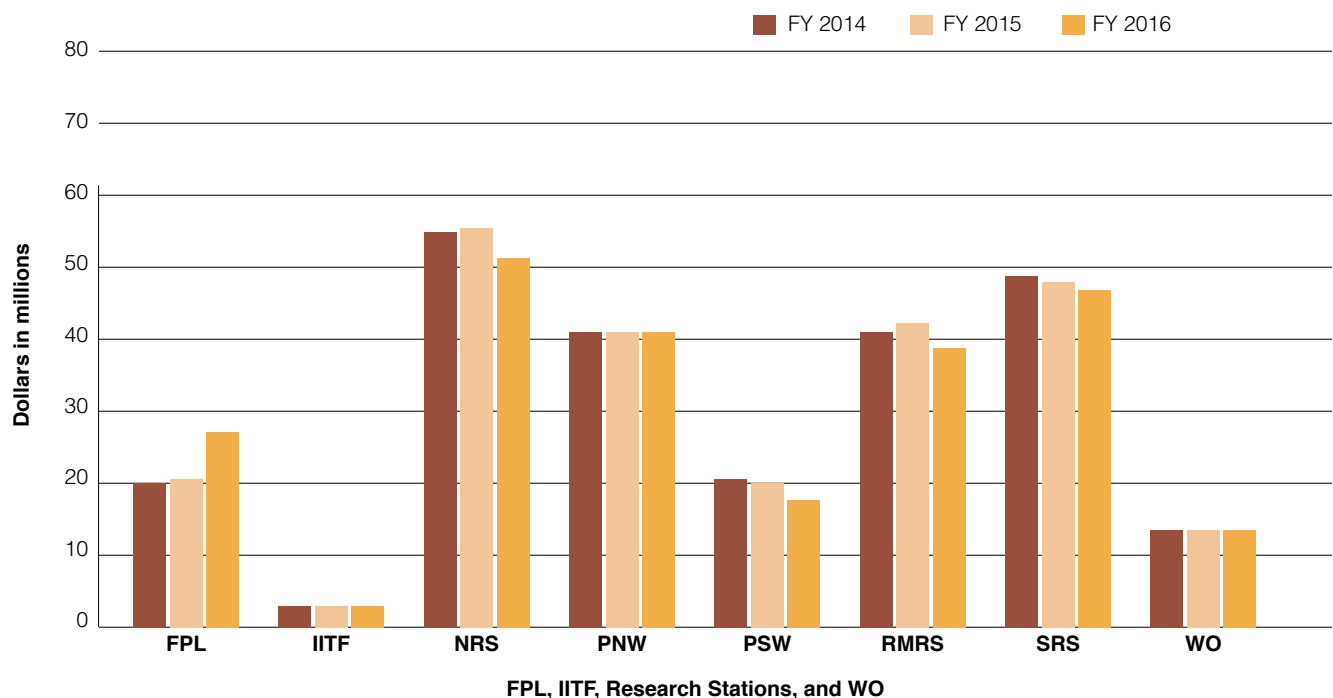


Figure 2. Funding to FPL, IITF, Research Stations, and Washington Office, FY 2014-2016. FPL = Forest Products Laboratory. FY = fiscal year. IITF = International Institute of Tropical Forestry. NRS = Northern Research Station. PNW = Pacific Northwest Research Station. PSW = Pacific Southwest Research Station. RMRS = Rocky Mountain Research Station. SRS = Southern Research Station. WO = Washington Office.

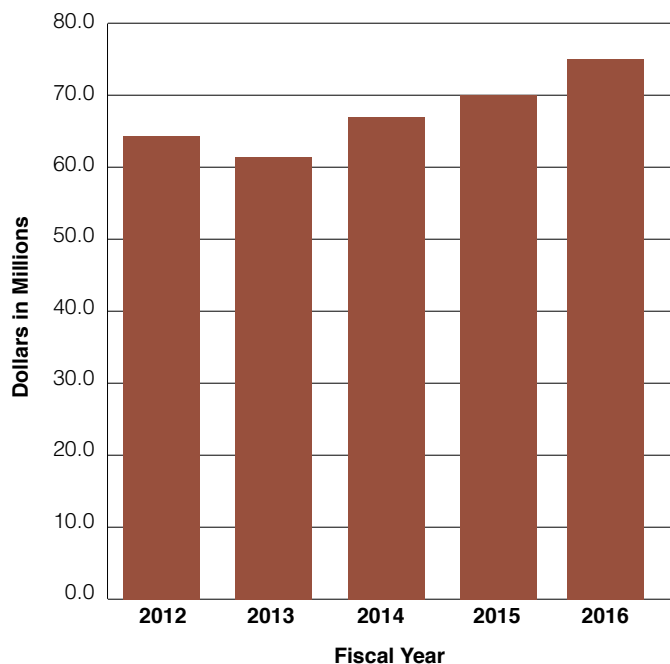


Figure 3. Trend showing allocation of Forest Inventory and Analysis funds from fiscal years 2012-2016.

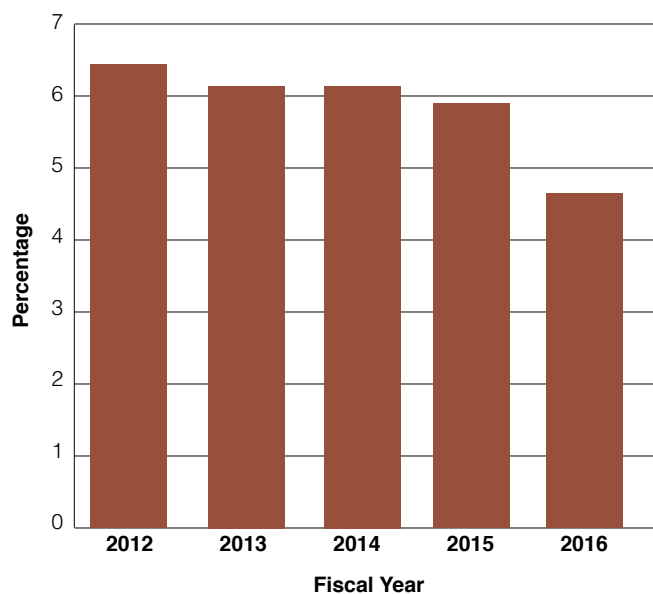


Figure 4. Research and Development's appropriation as percentage of Forest Service appropriation.

Table 2. Summary of budget changes for fiscal years 2012–2016 (dollars in thousands).

	2012	2013	2014	2015	2016
Forest Service Appropriation^a	4,844,922	4,556,649	4,896,611	5,073,246	5,680,346
Research Appropriation	214,830	222,040	222,040	211,320	227,418
Facility Maintenance Fund	3,613	4,117	3,960	3,960	4,680
Forest Inventory and Analysis (FIA)	64,269	60,907	66,805	70,000	75,000
Subtotal, Research (fund FRFR/ program FRRE)	295,300	279,854	292,805	296,000	291,000
National Fire Plan (FRFR/FRF2)	21,699	20,603	19,795	19,795	19,795
Forest Resource Information and Analysis (SPIA)	4,917	4,660	0	0	0
Joint Fire Science Program (FRJF)	7,250	6,884	6,914	6,914	6,914
Facilities & Deferred Maintenance (CMCM & DMDM)	4,500	3,751	4,309	3,283	6,313
Total, Research	333,666	315,752	323,823	325,992	324,557
Percent of Research Dollars from Forest Service Appropriation	6.9%	6.9%	6.6%	6.4%	5.7%
Forest Service Research Grants & Agreements (Extramural)	41,978	38,154	42,618	42,618	49,984
Percent of FRFR (= FRRE + FRF2+ FRJF) Budget in Grants and Agreements	12.9%	12.4%	13.3%	13.2%	15.7%
Number of Research Grants & Agreements	649	581	746	577	643
Research Full-Time Employees					
(Total of FRRE + FRF2+ FRJF FTEs)	2,052	1,933	1,861	2,036	1,917

FRRE, FRFR, FRF2, FRJF, SPIA, CMCM, DMDM, and SPIA are Forest Service accounting codes.

^aDiscretionary appropriation.

FOREST SERVICE STRATEGIC PLAN

The *USDA Forest Service Plan: FY 2015–2020* provides the strategic direction that guides the agency in delivering its mission and identifies major current issues important to natural resource management. The direction and issues are addressed in four strategic goals:

STRATEGIC GOAL:

Sustain Our Nation's Forests and Grasslands

Strategic Objective A.

Foster resilient, adaptive ecosystems to mitigate climate change

Strategic Objective B.

Mitigate wildfire risk

Strategic Objective C.

Conserve open space

STRATEGIC GOAL:

Deliver Benefits to the Public

Strategic Objective D.

Provide abundant clean water

Strategic Objective E.

Strengthen communities

Strategic Objective F.

Connect people to the outdoors

STRATEGIC GOAL:

Apply Knowledge Globally

Strategic Objective G.

Advance knowledge

Strategic Objective H.

Transfer technology and applications

Strategic Objective I.

Exchange natural resource expertise

MANAGEMENT GOAL:

Excel as a High-Performing Agency

Management Objective A.

Recruit a diverse workforce

Management Objective B.

Promote an inclusive culture

Management Objective C.

Attract and retain top employees

Forest Service R&D aligns its work with the agency's strategic goals through its Strategic Program Areas.

STRATEGIC PROGRAM AREAS

The scope of R&D's work span a range of research. In 2005, R&D organized its breadth of research into seven Strategic Program Areas (SPAs). SPAs support an integrated approach to the study of broad, complex environmental and social issues. SPAs also provide strategic subdivisions of the national Forest Service research program for purposes of program development; management of reviews and oversight; communication to national audiences, including nongovernmental organizations, the administration, Congress, and the general public; budget formulation and presentation; and, the fostering of collaboration among research stations and external partners. The seven SPAs are as follows:

- The **Wildland Fire and Fuels SPA** provides the knowledge and tools that managers use to reduce negative effects and enhance beneficial effects of fire and of fire and fuels management on society and the environment. The SPA has five major focus areas: (1) the understanding and modeling of fundamental fire processes, (2) interactions of fire with ecosystems and the environment, (3) social and economic aspects of fire, (4) evaluation of integrated management strategies and disturbance interactions at multiple scales, and (5) application of fire research to address management problems.
- The **Invasive Species SPA** provides scientific information, methods, and technology to understand, reduce, minimize, or eliminate the introduction, establishment, spread, and effects of invasive species (and interactions with disturbance) and to restore ecosystems affected by invasive species or restore their function. The SPA focuses on plants, animals, fish, insects, diseases, invertebrates, and other species that are not native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm.
- The **Outdoor Recreation SPA** provides human and ecological sustainability through research directed at understanding and managing outdoor environments, activities, and experiences that connect people with the natural world. Research in this SPA is interdisciplinary and focuses on: nature-based recreation and changing trends in American society; connections among recreation visitors, communities, and the environment; human benefits and consequences of recreation and nature contact; the effectiveness of recreation management and decision making; and the sustaining of ecosystems affected by recreation.
- The **Resource Management and Use SPA** provides the scientific and technological base to sustainably manage and use forest and range resources and forest fiber-based products. Focus areas include plant sciences, soil sciences, social sciences, silviculture, genetics, productivity, forest and range ecology management, harvesting and operations, forest and biomass products and utilization, global change, economics, and urban forestry.
- The **Water, Air, and Soil SPA** allows for the sustainable management of these essential resources by providing clear air and safe drinking water. The SPA features ecosystem services with a high level of integration among water, air, and soil research. It stresses the effects of climate variability and change on water budgets, and it focuses on carbon sequestration from an ecosystem perspective.
- The **Wildlife and Fish SPA** relies on interdisciplinary research to inform policy initiatives and management strategies affecting wildlife and fish habitat on private and public lands and the recovery of threatened or endangered species. Scientists in this SPA investigate the complex interactions among species; ecosystem dynamics and processes; land use and management; and emerging broad-scale threats, including global changes in climate, loss of open space, invasive species, and disease.
- The **Inventory and Monitoring SPA** provides the resource data, analysis, and tools needed to effectively identify the current status and trends of forests; management options

and effects; and threats and effects of fire, invasive insects, disease, and other natural processes, enhancing use and value of the Nation's forests and grasslands. Assessing current and potential effects of changes in climate depends on monitoring forest ecosystems that are at the greatest risk to rapid changes in climate. Focus areas include the development and use of integrated interdisciplinary science, technologies, and remote sensing to increase the timeliness and spatial resolution of forest fragmentation

caused by land use change; the describing of the incidence of invasive insects, disease, and fire; understanding forest carbon pools; and reducing the effects caused by extreme weather events.

Figure 5 shows the trends in funding allocated to each SPA for FYs 2013-2016; table 3 shows the total resource investments allocated to each SPA for FY 2016.

Figure 5. Trend showing funding allocated to each Strategic Program Area from fiscal years (2013- 2016).

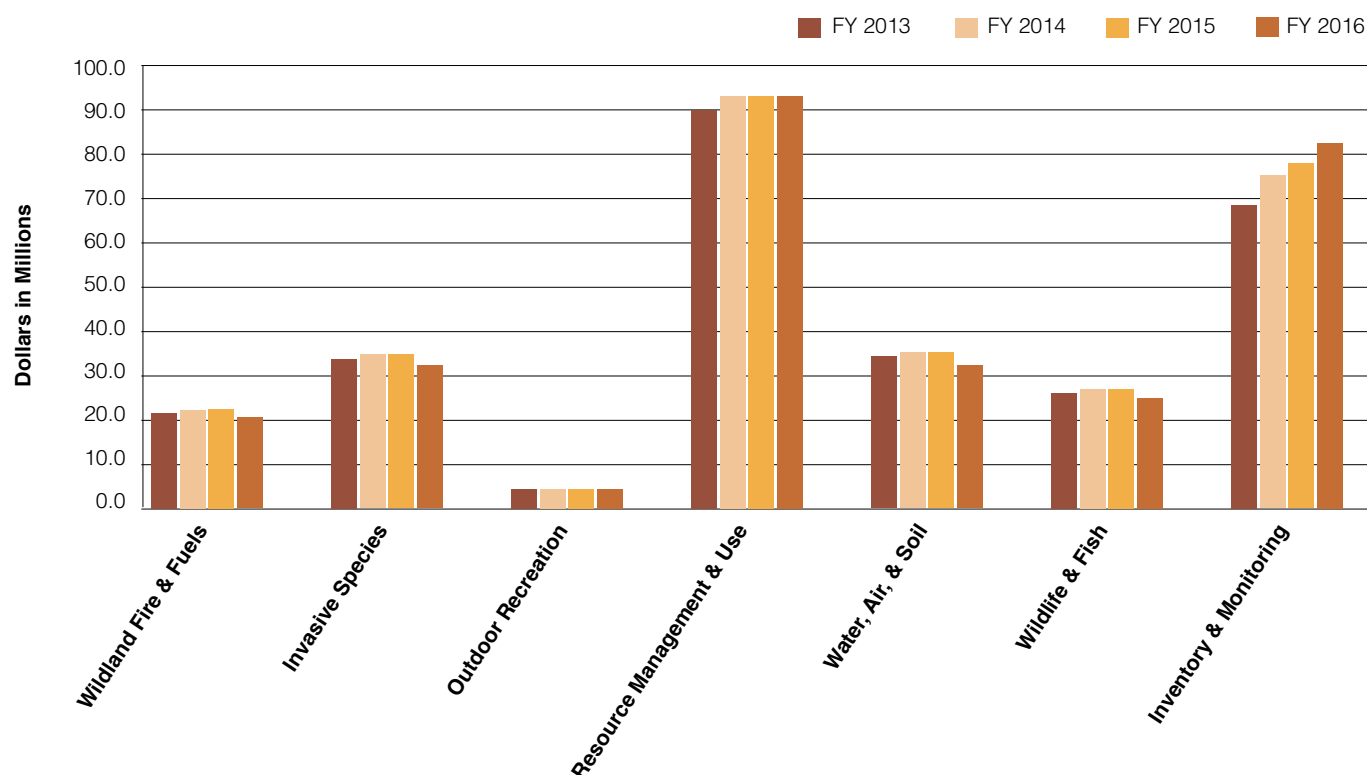


Table 3. Funding allocated to each Strategic Program Area for FY 2016.

Strategic Program Areas	Total Resource Investment per SPA FY 2016 (dollars in thousands)
Wildland Fire and Fuels	21,180
Invasive Species	33,552
Outdoor Recreation	4,228
Resource Management and Use	89,250
Water, Air, and Soil	33,823
Wildlife and Fish	25,928
Inventory and Monitoring	83,039
Total R&D Budget	\$291,000
Total Goal	\$127,603

R&D = Research and Development. SPA = strategic program area.

RESEARCH ACCOMPLISHMENTS THAT SUPPORT AGENCY GOALS AND OBJECTIVES

Using funds appropriated to each SPA, R&D provides science and science-based tools to address the complexities of the Nation's public and private forests, rangelands and grasslands, thereby supporting agency goals and their respective objectives. Below are examples of research accomplishments that are representative of how R&D meets the agency's strategic goals.

Strategic Goal:

Sustain Our Nation's Forests and Grasslands

The national forests and grassland were established to protect the land, secure favorable water flows, and provide a sustainable supply of goods and services to the American people. Forest Service R&D provides land management tools and knowledge to the States, private forest landowners, and the National Forest System (NFS). To support this strategic goal and its objectives (A, B, C), each SPA was allocated the amount of funds shown in table 4.

Table 4. Funds allocated to each Strategic Program Area to "Sustain Our Nation's Forests and Grasslands."

Strategic Program Area	FY 2016 (dollars in thousands)
Wildland Fire and Fuels	10,655
Invasive Species	16,208
Outdoor Recreation	2,141
Resource Management and Use	45,053
Water, Air, and Soil	17,170
Wildlife and Fish	15,510
Inventory and Monitoring	18,214
Total funds allocated	\$124,951

Strategic Objective A:

Foster resilient, adaptive ecosystems to mitigate climate change

Resources help land managers adapt to a changing climate. A collaborative team of scientists and managers developed the Adaptation Workbook to help land managers incorporate climate change considerations into real-world projects for natural resource management and conservation (fig. 6). Hundreds of land managers have used the Adaptation Workbook, helping to create more than 185 adaptation demonstrations that provide examples of on-the-ground climate change adaptation. More than 3,000 copies of the general technical report have been distributed to public, private, and tribal natural resource organizations since its initial release in 2012. Visit www.forestadaptation.org/demos for videos of examples and www.adaptationworkbook.org for an online version of the workbook.

RESEARCH ACCOMPLISHMENTS THAT SUPPORT AGENCY GOALS AND OBJECTIVES



Figure 6. The Adaptation Workbook online tool (adaptationworkbook.org) is a structured tool for land managers to use to integrate climate change into management plans. Users of the tool draw from ecosystem vulnerability assessments published by the Northern Research Station.

Photo courtesy of Danielle Shannon, Northern Institute of Applied Climate Science.

Strategic Objective B:

Mitigate wildfire risk

Potential fire behavior depends on cutting pattern in a Montana lodgepole pine forest. In 2000, lodgepole pine stands in Montana were cut and prescribed-burned in two patterns: one resulted in evenly spaced trees and the second resulted in clumps of trees separated by clearcut openings (fig. 7). The objective was to evaluate these treatments as ways of restoring forests and managing fire behavior. The questions asked were: does cutting pattern and use of prescribed fire influence fuel dynamics, and are there differences in potential fire behavior due to cutting patterns and the burn treatments? Because fires burn on the ground surface and in the crowns of trees, the amount of fuel on the surface and in the tree crowns were calculated. Statistical models were used to estimate the probabilities that fires would burn and spread on the surface, move (transition) into the crowns, and spread through the forest. More trees were blown down in the evenly spaced treatment compared to the clumped treatment. Mortality from the prescribed fires was similar in both cutting patterns. There was an overall reduction of fine surface fuels in logged stands, especially the burned units, which would reduce the spread of surface fire. It was more likely that a surface fire would



Figure 7. Satellite imagery of clumped (lower left) and dispersed retention (upper right) at Tenderfoot Creek Experimental Forest, Montana.

Photo courtesy of the USDA Forest Service.

RESEARCH ACCOMPLISHMENTS THAT SUPPORT AGENCY GOALS AND OBJECTIVES

transition to the crown on treated plots, but crown fires were less likely to spread compared to the untreated plots. Cutting and burning treatments in lodgepole pine forests can create complex structure in lodgepole forests and promote resilience to wildfire.

Strategic Objective C:

Conserve open space

Advancing Sustainability Through Urban Green Space: Cultural Ecosystem Services, Equity, and Social Determinants of Health. There is a pressing need to understand the role of urban green spaces on human health and well-being. Urban green spaces provide an array of

benefits, or ecosystem services, that support physical, psychological, and social health (fig. 8). In many cases, these benefits are not equitably distributed across diverse urban populations. Southern Research Station scientists have strategically connected this topic to frameworks in ecosystem services, social determinants of health, and environmental justice. The scientists explored relationships between urban green space and the social determinants of health; examined cultural ecosystem services as nature-based health amenities to promote social equity; and recommended that future research examines links between urban green space and public health within the context of environmental justice.



Figure 8. As urban natural resource stewardship is a priority at the Forest Service, it is critical to understand how the distribution of urban green spaces can influence public health amongst diverse communities.

Photo courtesy of USDA Forest Service.

Strategic Goal:

Deliver Benefits to the Public

The public demand for high-quality outdoor recreational experiences places pressure on the ecological integrity of national forests and grasslands. The combination of increasing U.S. populations and declining public access to privately owned forest land creates demand for public lands to provide more recreational opportunities. Forest Service R&D must emphasize effective management solutions that have a solid scientific foundation. Forest Service R&D examines the effects of changing demographics and people’s perceptions of the value, importance, and opportunities created by healthy forests and rangelands. This research helps communities understand the relationship between the quality of the recreation experience and the importance of ecological integrity to maintain recreational opportunities into the future. To support this strategic goal and its objectives (D, E, F), each SPA was allocated the amount of funds shown in table 5.

Table 5. Funds allocated to each Strategic Program Area to “Deliver Benefits to the Public.”

Strategic Program Areas	FY 2016 (dollars in thousands)
Wildland Fire and Fuels	1,815
Invasive Species	4,500
Outdoor Recreation	1,055
Resource Management and Use	18,631
Water, Air, and Soil	5,082
Wildlife and Fish	2,545
Inventory and Monitoring	21,545
Total funds allocated	\$55,173

Strategic Objective D:
Provide abundant clean water

New insights into how forests provide clean, secure water supplies. Studies of the variation in the isotopic composition of water were used to determine the time that it took forest water to reach a stream (fig. 9). The times varied from a median of 50 days during wet periods to 190 days during dry periods. At all times, there is a very small portion of the streamflow that is much older—as old as several years. These variations in water travel time matched changes in concentrations of substances dissolved in water, demonstrating how variations in water sources regulate water quality. These results will help forest managers understand mechanistically how forests function to provide a clean and reliable water supply and provide a benchmark for determining how climate change will affect this valuable resource in the future.

In addition to conducting studies in clean air to deliver benefits to the people, a study was conducted using moss as bioindicators of environmental health.

Tree moss can be used as an inexpensive bioindicator of air pollution in complex urban environments. A research team used moss bio-indicators and mathematical spatial regression modelling to develop fine-scale maps of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in Portland, OR. Moss (*Orthotrichum lyellii*) samples were collected from 346 sites across Portland in December 2013 and tested for 18 PAHs and 22 elements, including several toxic metals such as lead, cadmium, and chromium (fig. 10). Initially, the science team was concerned with air pollution from polycyclic aromatic hydrocarbons, a class



Figure 9. Scott Bailey collecting a sample of water from Hubbard Brook. In the winter, a pick is used to chop a hole in the ice to access flowing water for sampling.
Photo courtesy of Scott W. Bailey, USDA Forest Service.

STRATEGIC GOAL: DELIVER BENEFITS TO THE PUBLIC

of potent environmental toxins emitted by the burning of fossil fuels and wood. The scientists added in heavy metals because the laboratory analysis was relatively inexpensive. Cadmium was a top concern of the Oregon Department of Environmental Quality (DEQ) because a 2011 DEQ study found discrepancies between predicted and observed concentrations of the metal at Portland's one permanent air-quality monitoring site. Cadmium is linked to health problems such as kidney disease and cancer. When their moss sample results came back from the lab, the science team spatially modeled the data to create a fine-scale map of cadmium deposition across the city. Their preliminary results revealed two significant "hotspots" of cadmium levels in moss, both of which were centered on two stained-glass manufacturers. Out of concern for public health, the scientists shared their findings with Oregon DEQ, which responded in October 2015 by placing a mobile air-quality monitoring instrument adjacent to one cadmium hotspot and taking 24-hour readings over the course of nearly a month. This was a necessary step because it was unknown how

well concentrations in moss correlated with those in the air. Their results confirmed the high levels of cadmium found in the moss, showing mean cadmium concentrations in the air 49 times higher than Oregon's State benchmark. The study shows that moss bioindicators have the potential to improve air-quality monitoring by serving as a screening tool to help cities strategically place their air-quality monitors.

Strategic Objective E:

Strengthen communities

Engaging African American forest owners in sustainable forest management. The Sustainable Forestry and African American Land Retention Program (SFLR) was initiated in 2012 to improve forest management by connecting African American landowners to organized networks of forestry support including Federal and State government programs, businesses, and nonprofit conservation, legal, and community development organizations. SLFR is a partnership of the U.S.



Figure 10. A scientist gathers a moss sample from a neighborhood tree in Portland, OR.

Photo courtesy of Julie Johnson, USDA Forest Service.

STRATEGIC GOAL: DELIVER BENEFITS TO THE PUBLIC



Figure 11. John Schelhas discusses family land history with Eleanor Cooper Brown in South Carolina.

Photo courtesy of Sarah Hitchner, University of Georgia, Athens.

Endowment for Forestry and Communities (Endowment), USDA Natural Resources Conservation Service, and USDA Forest Service. Three community-based pilot projects began in North Carolina, South Carolina, and Alabama. Researchers conducted qualitative interviews on landownership and forestry-related issues with 60 African American landowners in the three States (fig. 11). The results showed that while land represents an important family resource across generations, heirs' property status often results in insecure property ownership and most families receive little or no economic return from their land. Landowners expressed broad interest in future engagement in forestry activities and managing for wildlife because of how forestry can help families retain land and build assets. Interviews revealed that the community-based pilot projects were building links among landowners and foresters to encourage sustainable forest management and retention of African American family land.

Strategic Objective F:

Connect people to the outdoors

1000 Herons project uses technology to monitor movements of two herons and two egrets. This program is a partnership between the Northern Research Station and 1000 Herons, a nonprofit run by John Brzorad, a researcher at Lenoir-Rhyne University in North Carolina. The Forest Service and partners sponsored two herons and two egrets for tracking (daily, seasonally, and annually), enabling data-driven instruction in partner schools in Baltimore, MD, Philadelphia and Newtown Square, PA, and New York City. In Philadelphia, students used the data to explore all aspects of ecology, including habitats and landforms, ancient birds and their evolution to modern birds, adaptation, and migration. Students also predicted future movements, and explored potential new habitat for their bird (fig. 12). In New York City, a partner school found tracking one egret inspired an interest in bird watching, and is working to integrate the newly acquired bird studies at the school. In the coming year, bird data will be used at more grade levels. Even hiccups in the data, such as temporary loss of transmissions and predation of one bird, provided opportunities for students to learn the ups and downs of science and data collection.



Figure 12. Threebe in Baltimore, looking regal after being fitted with his transmitter. The harness expands as the bird grows, and the transmitters are very lightweight.

Photo courtesy of Harriet Van Kleeck, volunteer.

Strategic Goal:

Apply Knowledge Globally

Forest Service R&D provides science and technology solutions for clients’ and partners’ priority issues in ways they find effective and useful for sustainably managing forests and grasslands. To support this strategic goal and its objectives (G, H, I), each SPA was allocated the amount of funds shown in table 6.

Table 6. Funds allocated per Strategic Program Area to “Apply Knowledge Globally.”

Strategic Program Areas	FY 2016 (dollars in thousands)
Wildland Fire and Fuels	7,221
Invasive Species	7,805
Outdoor Recreation	1,131
Resource Management and Use	35,941
Water, Air, and Soil	11,174
Wildlife and Fish	8,040
Inventory and Monitoring	39,564
Total funds allocated	\$110, 876

Strategic Objective G:
Advance knowledge

Bark beetles and wildfires: new tools provide insights. Bark beetles have affected millions of acres of western forests and sometimes contribute to highly unpredictable fire behavior. Fire fighters are increasingly being exposed to fires burning in mixtures of dead and live trees in bark beetle-impacted

forests, yet there is limited understanding of bark beetle effects on fire behavior.

Two new physics-based models, The Wildland Fire Decision Support System (WFDSS) and HIGRAD/FIRETEC, are providing insights into how and why bark beetle-caused tree mortality affects fire behavior in ways that operational models cannot. These models can provide insights into how fires might behave under fluctuating winds, in mixtures of varying fuel moistures such as bark beetle-affected forests, or in areas with a heterogeneous distribution of surface and canopy fuels (fig. 13). Physics-based fire models are providing insights to better understand how and why bark beetle-caused mortality alters fire behavior and identify “watch out” situations for fire fighters. Research to date has revealed that bark beetle-impacted forests can exhibit rapid rates of spread through time even under moderate fire weather conditions with relatively low winds. This work is helping to inform current and future land managers who are dealing with large areas impacted by bark beetles as well as guide new experiments and measurements related to the effects of bark beetle mortality on fire behavior.

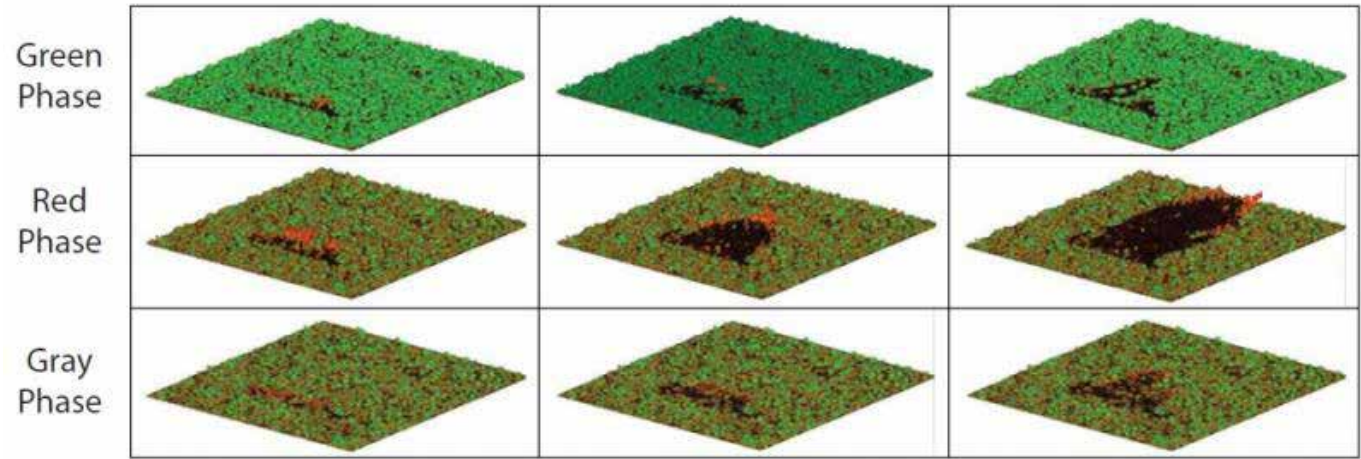


Figure 13. FIRETEC simulations of fire perimeter and fuel consumption through time for pinyon-juniper woodland during the green, red, and gray phases of a pinyon Ips bark beetle attack. Time proceeds from left to right.

Photo courtesy of USDA Forest Service.

STRATEGIC GOAL: APPLY KNOWLEDGE GLOBALLY

Strategic Objective H:

Transfer technology and applications

Laser technology and modeling tools for precision forest inventory, monitoring, and planning. Researchers are developing relationships between LiDAR (Airborne Light Detection and Ranging) estimates and traditional forestry measures collected on the ground to develop maps of forest biomass and predict changes over time (fig. 14). They used two LiDAR surveys of Idaho's Moscow Mountain to map forest biomass in 2003 and 2009. They calculated forest biomass change over the 6-year period and used the climate-sensitive version of the Forest Vegetation Simulator (Climate-FVS) to simulate expected effects of climate change on forest productivity over the next 100 years. Managers can benefit from this precise, spatially explicit information for forest planning as climate changes into the future. Repeat LiDAR surveys are useful for accurately quantifying high resolution, spatially explicit biomass and carbon dynamics in conifer forests.

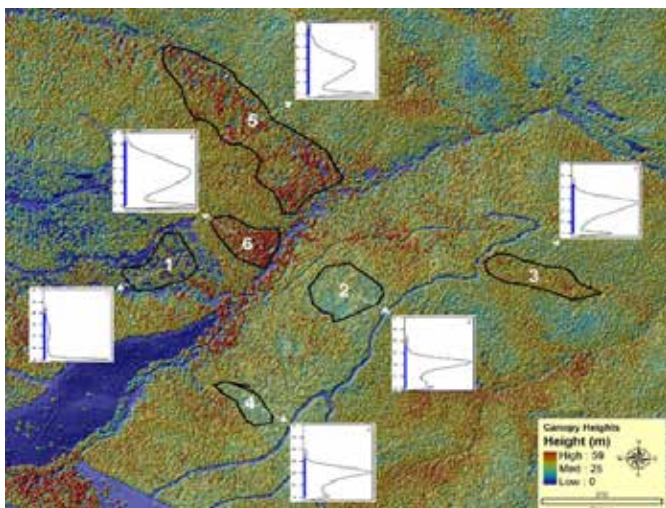


Figure 14. Example of high-resolution LiDAR data of canopy heights.

Photo courtesy of USDA Forest Service.



Figure 15. Tribal acorn gatherers and scientists gather underneath an actively tended black oak tree near North Fork, CA.

Photo courtesy of Jonathan Long, USDA Forest Service.

Strategic Objective I:

Exchange natural resource expertise

Restoring California black oaks sustains cultural and ecological values. Mature California black oaks have a “Goldilocks” relationship with fire. A lack of fire (“too cool”) allows shade-tolerant conifers to crowd out the oaks, while more intense fire (“too hot”) typically kills the oak stems. Trees need many decades to grow large enough to produce acorns and large cavities used by animals such as fisher. But landscape alterations, either through the exclusion of fire or emergence of high-intensity, landscape-scale wildfires, are making it harder for California black oaks to thrive in their former abundance. A research team led by PSW ecologist Johnathan Long and Frank Lake and with partners from the North Fork Mono Tribe, NRCS, UC Extension and Sierra National Forests synthesized research on the values and opportunities associated with restoring California black oak (PSW-GTR-252) (fig. 15). The report integrates tribal traditional ecological knowledge with findings from local agency projects and scientific studies regarding black oak and associated plants, fungi and wildlife. The report outlines a landscape-scale strategy that targets intensive thinning and fuels reduction to facilitate broader return of low-intensity fire, as was traditionally used by Native Americans.

Management Goal:

Excel as a High-Performing Agency

Forest Service is fundamentally a science-based agency. In 2014, R&D realigned its structure to better provide science-based applications and tools for sustainable management, collaborative science programs and research, while developing the scientific talent needed to lead and deliver high-quality research results.

Management Objective A:

Recruit a diverse workforce

Forest Service R&D's success depends also on a diverse workforce to: maintain a competitive edge, for heterogeneity, to improve managerial decision making and productivity, and to value and draw on intrinsic differences and strengths among employees. Forest Service R&D provided detail opportunities and supported participation in leadership development programs for its diverse workforce.

Management Objective B:

Promote an inclusive culture

A diverse workforce also fosters an inclusive culture, attracts and retains highly qualified and skilled employees and fosters a work environment that enable and motivate employees to contribute to the agency's mission accomplishments. Here are a few of the R&D accomplishments:

- Provided funding in the amount of \$2,500 to the Ecological Society of America's Strategies for Ecology Education, Diversity and Sustainability (SEEDS) program to: (1) increase student understanding of forest ecosystems and functioning, particularly among undergraduate students from underrepresented minority backgrounds; (2) increase visibility of Forest Service careers and opportunities; and (3) promote diverse leadership in policy, communication, and outreach to enhance understanding of sustainable forests and forest ecosystem services.
- Provided funding for two student interns to attend the Conference on Asian Pacific American Leadership (CAPAL). R&D provided funding to support two student interns, and the Oak Ridge Internship for Science and Education (ORISE) fellows provided opportunities for two interns under the Resource Assistant Program through partnership with two organizations: the Greening Youth Foundation and Mobilized Green.
- Partnered and sponsored, at the agency level, the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) meeting. SACNAS is a

society of scientists dedicated to fostering the success of Chicano/Hispanic and Native American scientists—from college students to professionals—to attain advanced degrees, careers, and positions of leadership in science.

- Participated in the Minorities in Agriculture, Natural Resources, and Related Sciences (MANRRS) 31st Annual Career Fair and Training Conference. During the career fair, Forest Service R&D employees aided in recruiting students for 11 summer intern positions. Participating units included WO R&D, Northern Research Station, Southern Research Station, Region 8, and other USDA agencies.

Management Goal C:

Attract and retain top employees

In FY 2016, Forest Service R&D:

- Recognized the appointment of five Super Scientists (ST). ST is the highest level that a scientist in the Federal Government can achieve. It involves performance of high-level research and development in the physical, biological, medical, or engineering sciences, or a closely related field.
- Recognized four scientists at the R&D Deputy Chief's Awards Ceremony in February 2016 for their outstanding contributions to research and science delivery. The individual receiving the Early Career Scientist award was also nominated for the Presidential Early Career Awards for Scientists and Engineers (PECASE). The PECASE award represents the highest honor that any young scientist or engineer can receive in the United States.
- Continued support of the Early Career Scientist Cadre development program. The program, initiated in 2015 to increase the morale, productivity, and impact of the new generation of Forest Service scientists, is directed at advancing the agency's strategic goals of attracting and retaining top employees.
- Sponsored two seminars through the Southern Research Station Women in Science Initiative for all scientists and the Early Career Scientist national cadre on working internationally to enhance research credentials.

MANAGEMENT GOAL: EXCEL AS A HIGH-PERFORMING AGENCY

- Continued to support the 10 Scientists Initiative which is designed to support 10 entry-level scientists.
- Continued participation in the cross-deputy area improvement of the onboarding process to retain new hires. A new employees guide was made available to new employees.
- Sponsored a virtual training session aimed at: teaching research scientists how the Research Grade Evaluation

Guide (RGEG) Panel process works; helping prepare a research grade (four-factors) position description; and helping plan for their research and program of work. Presentations and panel discussions were provided by senior research leaders and a senior scientist. The research leaders offered perspectives on topics such as building your career, how to represent your accomplishments, and professional society engagement.

PRIORITY RESEARCH AREAS

Our Nation's forests, grasslands, and urban environments face increasing pressure from human and environmental threats, including climate change, pollution, growing human populations, and increasing energy demands. Forest Service R&D addresses these issues through its Priority Research Areas (PRAs). The PRAs are the broad level current and emerging research issues that impact our National Forests. The capacity of Forest Service R&D to address the PRAs are contained in the Strategic Program Areas (SPAs). The PRAs and SPAs demonstrate R&D's commitment to remaining an interactive, vibrant, and visionary partner in solving today's critical problems with science and technology.

1. **Forest Disturbance**—Research to improve the resiliency of forests, rangelands, and aquatic areas and to mitigate the adverse effects of climate change, including wildfire. This research includes studies addressing the effects and effectiveness of hazardous fuels treatments and biomass use.
2. **Forest Inventory and Analysis**—Research to make and keep current a comprehensive inventory and prospective future of the Nation's forest resources. The program surveys landowner objectives and values, partners with

State forestry agencies to maintain field-based inventory of all ownerships, and conducts woodflow surveys of all primary wood-using facilities in the United States.

3. **Watershed Management and Restoration**—Research to promote the best management practices designed to protect and restore watersheds that enhance water quantity and quality.
4. **Bioenergy and Biobased Products**—Research to advance alternative energy sources and new markets that contribute to energy security and independence while reducing greenhouse gases.
5. **Urban Natural Resources Stewardship**—Research to improve the management, protection, and stewardship of urban natural resources to improve people's lives.
6. **Nanotechnology**—Research and technology to provide leading-edge innovations in the development of wood products.
7. **Localized Needs**—Research targeted to the geographic regions served by Forest Service research stations and field laboratories.

PRIORITY RESEARCH AREAS

Table 7. Allocation of funds per Strategic Program Area to conduct research to address Priority Research Areas issues.

Priority Research Areas	Strategic Program Areas ^a							Total
	Fire	Invasives	Recreation	Resource Management and Use	Water, Air, and Soil	Wildlife and Fish	Inventory and Monitoring	
Forest Disturbances	\$282	\$192	\$0	\$14,864	\$1,942	\$3,044	\$5,200	\$25,524
Forest Inventory and Analysis	\$0	\$0	\$0	\$0	\$0	\$0	\$75,000	\$75,000
Watershed Management and Restoration	\$1,778	\$1,155	\$0	\$2,865	\$9,372	\$5,777	\$879	\$21,826
Bioenergy and Biobased Products	\$235	\$93	\$0	\$11,033	\$235	\$0	\$328	\$11,924
Urban Natural Resource Stewardship	\$444	\$0	\$2,007	\$1,052	\$1,333	\$0	\$889	\$5,725
Nanotechnology	\$0	\$0	\$0	\$4,400	\$0	\$0	\$0	\$4,400
Localized Needs Research	\$18,441	\$32,112	\$2,221	\$55,036	\$20,941	\$17,107	\$743	\$146,601
Total	\$21,180	\$33,552	\$4,228	\$89,250	\$33,823	\$25,928	\$83,039	\$291,000

^aFunds are shown in thousands of dollars.

PARTNERSHIPS

Forest Service R&D consists of high-quality scientific research, applying findings to NFS lands, and making these findings available to others for application to their lands. Forest Service R&D distributes information and technology to land managers and land use planners using a variety of mechanisms, including publications, videos, training, and demonstrations. Forest Service R&D’s ability to interact with users of its research and transfer technology is substantially enhanced through partnerships, particularly those with other research organizations, land management practitioners, State agencies, urban planners, private forest owners, private organizations, and horticultural and agricultural interests.

These partners of Forest Service R&D include Federal and State agencies, universities, industry, nongovernmental organizations, tribal governments, and foreign government research cooperators.

Forest Service R&D has a long history of supporting extramural research through grants and agreements (G&As) with colleges and universities; State, local, and tribal governments; nonprofit organizations; industry; and individuals. In FY 2016, 643 G&As were issued and made, which was 11.4 percent higher than in FY 2015. The total G&As accounted for 17.8 percent of the Forest Service R&D budget in 2016.

Table 8. Number of grants and agreements and percentages of Forest Service R&D budget.

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Number of G&As	649	581	746	577	643
Percent of R&D budget	13	12	13	13	17.8

G&As = grants and agreements. R&D = Research and Development.

MEASURING FOREST SERVICE R&D PERFORMANCE

Since 2006, Forest Service R&D has conducted a customer satisfaction survey every 3 years. The survey is of the various people and groups that use Forest Service R&D research information and products, and identifies areas of high and low satisfaction with Forest Service R&D products and services. This information helps R&D identify where to maintain or improve the quality of service.

The first survey, conducted in 2006, documented satisfaction with R&D products because they are scientifically sound, accurate, and current. Also, scientists were considered authoritative sources who were able to provide stakeholders with clear, useful information and answers to their questions.

R&D staff were perceived to be courteous, knowledgeable, and timely in responding. Areas in need of improvement included making solutions to problems adequately detailed and workable with the resources customers had at hand, and for the issues they anticipated facing. The survey also identified a need for improving the availability of new products, recently released articles, and workshop schedules. In response to the 2006 survey, R&D initiated online tracking of publications and research products to make them more available to stakeholders online. This was the Research Information Tracking System (RITS) and the publicly accessible publication database, TreeSearch.

The second survey, in 2009, showed satisfaction with the design and presentation of material, with how knowledgeable and responsive R&D staff were, and the greater accessibility of information. To increase satisfaction, there was a need to better address and anticipate current and emerging problems of natural resource managers and other customers, to provide detailed workable solutions, and to provide even greater accessibility to products and services, including older publications. In response, R&D supported improved capacity for RITS, which was soon able to track, document, and make more accessible R&D products and services, expanding beyond scholarly publications. Numerous older legacy publications were then made accessible in TreeSearch. At the same time, the agency

worked to better align research to natural resource manager needs, with R&D and the NFS increasing efforts to work together on land management issues.

The third survey, in 2012, showed satisfaction with the relevance and quality of products, with how the issues customers faced were addressed, with the improved access to information, and with how well customers were informed about new products and services. Downloading publications from the web became the most popular method of accessing products, but respondents identified a need for improved online access to products and information. R&D recognized the need to more effectively deliver science to stakeholders and developed performance metrics to better evaluate outcomes in science delivery, technology transfer, and to help evaluate contributions to commercialization. In addition, R&D websites were overhauled to make information more accessible.

The fourth survey, in 2015, showed a decline in overall customer satisfaction, similar to that seen in most other surveys by Federal agencies, because of the fiscal sequestration across all Federal agencies. The survey found the greatest satisfaction related to the R&D staff, scientifically sound and authoritative products and services, ability of R&D to identify and address anticipated issues, and accessibility of products and services. The survey identified a need for more detailed and actionable solutions for stakeholders, and for greater relevance to current and anticipated issues. Since the FY 2015 survey, there has been a realignment of the WO R&D staffs and the creation and hiring of additional positions to improve communications, science delivery, and publicity, with a national coordinator for science delivery and communication and a new science writer. The realignment helped implement a coordinated approach to web delivery to make content more discoverable and better aligned with customer needs. The TreeSearch site was modified to improve its support of external sites like Google Scholar, a change that substantially increased its usage. A website was redesigned to create a better alignment with customer expectations.

MEASURING FOREST SERVICE R&D PERFORMANCE

Plans are underway to conduct the FY 2018 survey.

Table 9. Trends in Forest Service R&D Performance Outcomes.

Performance Measure	FY 2014	FY 2015	FY 2016
Customer satisfaction	79	76	76
Patent applications filed (5-year rolling average)	10	12	12
New inventions disclosed (5-year rolling average)	19	24	21
Patents issued (5-year rolling average)	4	9	6
Patent licenses executed	2	2	2
New interagency agreements and contracts	47	183	451
Interagency agreements and contracts continued	15	78	550
International cooperative agreements executed	0	17	0
Invasive species tools developed, delivered, and used (5-year rolling average)	168	258	274
Formally refereed publications	2,090	1,151	1,169
Informally refereed publications	384	862	853
Number of refereed publications	2,083	2,013	2,002
Number of science delivery products	49	442	310
Number of science delivery activities	1,224	2,513	2,744
Dollars of research funds awarded to institutions of higher learning	\$35,034,675	\$28,368,210	\$17,509,309
Dollars of research funding awarded to HBCUs, TCUs, and HSIs	\$950,615	\$1,025,624	\$849,484
Funding awarded to nonacademic institutions	\$15,667,381	\$13,908,476	\$20,956,918
Total amount of G&As awarded to other organizations	\$50,702,056	\$42,276,686	\$55,867,091
Leveraged funds from G&As (funds and in-kind services)	\$20,549,216	\$20,933,070	\$75,397,715
Fire quality efficiency index	4.5	5.2	4.7
Fire quality science index	3.4	4.2	4.2
Percentage of States for FIA data	98	98	100

FIA = Forest Inventory and Analysis. G&As = grants and agreements. HBCUs = Historically Black Colleges and Universities. HSIs = Hispanic Service Institutions. R&D = research and development. TCUs = Tribal Colleges and Universities.

WORKPLACE IMPROVEMENTS

The R&D Capital Improvement Program sustains a diverse portfolio of Agency Research & Development facilities, managed to provide mission, enabling facility infrastructure that is right-sized, environmentally resilient, and safe for all users.

Projects are selected through a collaborative “Choosing by Advantages” (CBA) process every 2 years, involving all the Station Engineers and R&D Leadership. Through

this process, project proposals are evaluated across a number of factors, which include the scope of the project, its impact on the Agency’s R&D mission, regulatory and policy compliance, and the estimated financial return on investment. Only the highest priority work, as determined by this CBA process, is funded every year. Projects completed in 2016 are listed below.

Table 10. Research and Development Capital Investment and Improvement Project by research station (FY 2016).

Region/Station/Area	State	Project Name and Type	Funding (\$1,000s)
RMRS	Montana	Fire Lab Burn Chamber/Wind Tunnel Upgrades — Phase I	1,600
RMRS	Montana	Fire Lab Burn Chamber/Wind Tunnel Upgrades — Phase II	541
PNW	Oregon	CFSL HVAC Repairs and Energy Upgrades — Phase I	1,090
PNW	Oregon	CFSL HVAC Repairs and Energy Upgrades — Phase II	970
PNW	Oregon	CFSL HVAC Repairs and Energy Upgrades — Phase III	1,712
SRS	Louisiana	Pineville Roof Replacement	400
Total:			\$6,313

CFSL = Corvallis Forestry Sciences Laboratory. FY = fiscal year. HVAC = heating, ventilation, and air conditioning. PNW = Pacific Northwest Research Station. RMRS = Rocky Mountain Research Station. SRS = Southern Research Station.
FY = fiscal year.

NATIONAL ACCOMPLISHMENTS

Most of the Forest Service research program is targeted to local and regional issues, executed by scientists at field locations and administered by research stations across the United States. Forest Service R&D also delivers products and services with a national scope, which are administered by Washington Office staff members at the headquarters or by those embedded in the field. In FY 2016, these national programs reported the following significant results:

- **Assessing Wildfire Risk:** New wildfire risk assessment methods form the scientific basis for the National Cohesive Wildland Fire Management Strategy, an effort of Federal, tribal, State, and local governments and nongovernmental organizations to collaboratively address the growing wildfire challenges. Forest Service researchers participate on analytical teams focused on furthering the science of wildfire risk analysis within the cohesive strategy and within other Federal programs, such as the Collaborative Forest Landscape Restoration Program.
- **Bolstering Sage Grouse Conservation:** Sagebrush ecosystems are among the largest and most threatened ecosystems in North America. Greater sage grouse has served as the bellwether for species conservation in these ecosystems and has been considered for listing under the Endangered Species Act several times. Forest Service scientists and managers prepared an assessment and plan that summarized its strengths, capabilities, partners, research, and potential future high-priority research areas for conservation and restoration of sagebrush and sage grouse. This work will help meet continuing widespread concerns and calls for science-based conservation to mitigate threats to sagebrush ecosystems, sage grouse, and other sagebrush-obligate species.
- **Visualizing How Climate and Management May Change Landscapes:** Forest managers need landscape modeling tools to project the consequences of management options while taking into account growth, disturbances, and climate; however, the overwhelming volume of output from such models makes it hard for managers and other stakeholders to interpret their projections. Forest Service scientists developed an intuitive, browser-based tool (LandViz) that allows stakeholders to easily visualize and analyze model output. LandViz enhanced the quality of managers' collaboration with model experts and increased their ability to interpret model outputs. It helps make the case for the need to manage in the context of change, rather than just attempting to maintain the status quo.
- **Controlling Emerald Ash Borers:** Emerald ash borer (EAB), a beetle from Asia that feeds on ash trees, was discovered in North America more than a decade ago. Land managers estimate EAB has killed hundreds of millions of ash trees in 27 States. To manage EAB, the U.S. Department of Agriculture is using biocontrol, a sustainable management approach that involves introducing specialized insect natural enemies from a pest's native range. Researchers are studying the impacts of EAB and biocontrol on ash survival, growth, and regeneration at long-term study sites in Michigan. Their findings indicate that biocontrol will improve ash tree regeneration in North American forests.
- **Carbon Accumulation by Forests May Slow:** U.S. forests currently help offset carbon emissions and reduce the overall costs of achieving emission targets, but that could change over the next 25 years. The accumulation of carbon stored in U.S. forests may slow in the future, primarily due to land use change and forest aging. Future declines in forest carbon sequestration could influence emission-reduction targets and impact the costs of achieving policy goals. Policies that encourage retaining or expanding forest land could enhance carbon sequestration levels over the next 25 years.
- **Changes in Water Quality Last More than 30 Years After Clearcutting:** After disturbances, healthy ecosystems are usually resilient enough to return to a pre-disturbance state. However, some disturbances are extreme

NATIONAL ACCOMPLISHMENTS

enough to permanently shift an ecosystem, a phenomenon known as a regime shift. In a study of the effects of clearcut logging, Forest Service scientists found surprising effects on water chemistry—effects that persisted almost 40 years after the experimental clearcut. In the clearcut watershed, dissolved nitrogen was higher, and the seasonal spike in nitrogen concentration had shifted from summer to winter.

- **Impacts of Drought:** Recent droughts have contributed to insect outbreaks, tree death, reduced tree growth, increased wildfire risk, and increased area burned by wildfire. These disturbances affect forest biogeochemical cycling and hydrologic processes. When combined with warmer air temperatures, droughts could have an even greater impact on forests and ranges. Forest Service scientists and their research partners recently edited a large-scale synthesis

on the prospect of increasing frequency and severity of future droughts. Management actions can either mitigate or exacerbate the effects of drought. This synthesis establishes the scientific foundation needed to manage forests for drought resiliency and adaptation.

- **World's Oldest Tree Species Resistant to Mountain Pine Beetle:** Mountain pine beetle (MPB) is the most significant mortality agent of pines throughout Western North America, and climate-driven range expansion is occurring. MPB is native to Western North America, and native pines have evolved defenses against the insect's attack. Great Basin bristlecone and foxtail pines occur at high elevations in the Great Basin region of the Western United States. These species have the longest lifespan of all trees worldwide and were found to have limited susceptibility to mountain pine beetles.

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at http://www.ascr.usda.gov/complaint_filing_cust.html and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992.

Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

