USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

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Science and Innovation for Conservation in the 21st Century

Highlighting Research and Development Accomplishments Through 2019

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U.S. Department of Agriculture
Forest Service
Washington, DC

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West of the Lizard Head Wilderness at the San Juan National Forest, CO. Photo courtesy of Martin Swett.

Introduction

This document presents examples of the U.S. Department of Agriculture (USDA), Forest Service's recent science and innovation accomplishments that benefit the public.

Forests are much more than just trees. Varied and valuable forested ecosystems are home to diverse species of fish and wildlife that people depend on for their food and livelihoods. These ecosystems contain watersheds that provide clean drinking water to millions of Americans, contribute billions of dollars to the U.S. economy each year in timber, herbs, seeds, and other commodities, and attract outdoor recreationists from around the world seeking beauty and adventure.

But forests are increasingly stressed by severe wildfires, invasive species, diseases, changing human demands, and other shifts in the environment. As a world leader in forestry research, the Research and Development (R&D) arm of the Forest Service generates the best science available so that land managers can keep forests healthy. Valuable information and innovative tools produced by R&D provide the foundation for science-based decision-making so that forests and grasslands will continue to provide resources for future generations.

Examples of how R&D benefits the public through science products and services:

- R&D research helps the Forest Service excel at customer service and provide key resources to the American people. For example, R&D research improves the quality and quantity of water to the American people by protecting water supplies from the National Forest System (NFS) lands. Water supplies from NFS lands—some of the Nation's highest quality surface waters—are the largest source of municipal water under single management in the United States. They provide clean drinking water to more than 60 million people in 3,400 communities, including large cities such as Los Angeles, Denver, and Atlanta.

Two members of the Idaho City Hotshots work on the Springs Fire on the Boise National Forest, August 2012. Forest Service research shows that prescribed burns can help prevent large wildfires. USDA Forest Service photo by Kari Greer.

- R&D research promotes shared stewardship by addressing cross-boundary and long-term land management questions and by collaborating with the land management community, the scientific community, other government agencies, industry, stakeholders, local communities, and other sectors in every stage of the research process–from data collection and publication to technology transfer and the application of discoveries, innovations, and technologies. For example, R&D develops cutting-edge, real-time risk management and decision support tools for strategically fighting fires, reducing fuel hazards, forecasting smoke, restoring burned ecosystems, and advising homeowners in the wildland-urban interface. These R&D innovations help protect firefighters, wildland communities, and natural resources.
- R&D research improves the condition of forest and grasslands by producing research that is incorporated into plans for the sustainable management of NFS forests and grasslands and helps conserve State and private forests and grasslands. R&D research supports forest resilience and restoration in the face of the full range of ecological stresses.
- R&D research enhances recreation by supporting the protection of fish and wildlife habitat, which improves recreational enjoyment on NFS lands. Also, R&D produces studies on the demand, carrying capacity, and economic impacts of recreation on NFS lands. These studies are used to help ease congestion and support long-term forest planning and recreation management.
- R&D research promotes human health by contributing to the development of new air quality monitoring techniques and by helping to identify new ways to reduce risks from diseases, such as Zika virus and Lyme disease.
- R&D research supports the development of cultivates innovative wood products that contribute creative new materials for construction, furniture production, consumer products, and the automotive, aerospace, electronics, and medical device industries. These contributions also create jobs for Americans.

R&D research results are freely available to the public and scientific community for their benefit and use.

Forest Service researcher helps land managers understand and counteract the impact of invasive species. USDA photo by Lance Cheung.

Research and Development lab research complements field research. USDA Forest Service photo.

Maintaining Pure and Plentiful Drinking Water

Drinking Water: Consider the Source

Forests provide people with clean, reliable drinking water. These waters, however, are at risk due to the needs of growing human populations, continued conversion of forests to other land uses, and anticipated changes in climate conditions. Given such threats, it is important to understand how much drinking water originates in forests, what populations and communities it serves, and how to best maintain water quality through proper watershed management. Forest Service studies that help characterize the contributions of the Nation's forests to water supplies include:

- A Rocky Mountain Research Station study published in 2015 showed that forests yield 46 percent of the mean annual water supply for the contiguous United States.
- A 2014 report published by the Southern Research Station showed that clean water begins in national forests for over 19 million people in the South—roughly the population of Florida. The report provides information on the amount of surface drinking water that national forest lands provide to communities in the South at a level of detail not previously available. This information can help support partnerships among State, Federal, and nongovernmental organizations that work to conserve the forest cover that provides the area's clean, dependable water supplies.

A lake lies before the Minarets in the Ansel Adams Wilderness, Inyo National Forest, CA. Photo courtesy of Ediza Lake.

Best Management Practices Improve Water Quality and Save Money

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

Forest Service scientists pioneered the first national program to strengthen implementation and monitoring of the BMPs used to protect water quality from the diverse range of ground-disturbing and management activities that occur on National Forest System lands. The National BMP Monitoring Program provides consistency for evaluating BMP implementation and effectiveness across all National Forest System units, which in turn enables the Forest Service, for the first time, to report national performance results to regulatory agencies, States, Tribes, other stakeholders, and the public. The consistency of the monitoring program is expected to result in improved water quality and millions of dollars of savings through simplified and streamlined monitoring approaches that contribute to the success of both local and national adaptive management strategies.

Research and Development played a key role in developing Best Management Practices protocols and has trained hundreds of Forest Service employees how to implement these protocols. USDA Forest Service photo.

New Tools Influence Decision on Road Rules

Roads may funnel rainwater and sediment into streams and rivers. Therefore, a poorly placed or poorly designed road can help degrade local water quality, increase erosion, and promote risks from landslides and other hazards.

To help managers minimize the impacts of roads, Forest Service researchers and partners developed analytical tools known as the Geomorphic Road Analysis and Inventory Package (GRAIP), which can be used to identify specific areas where water drains off forest roads and carries unwanted sediment into waterways.

Forests Provide Cost Savings for Water Providers

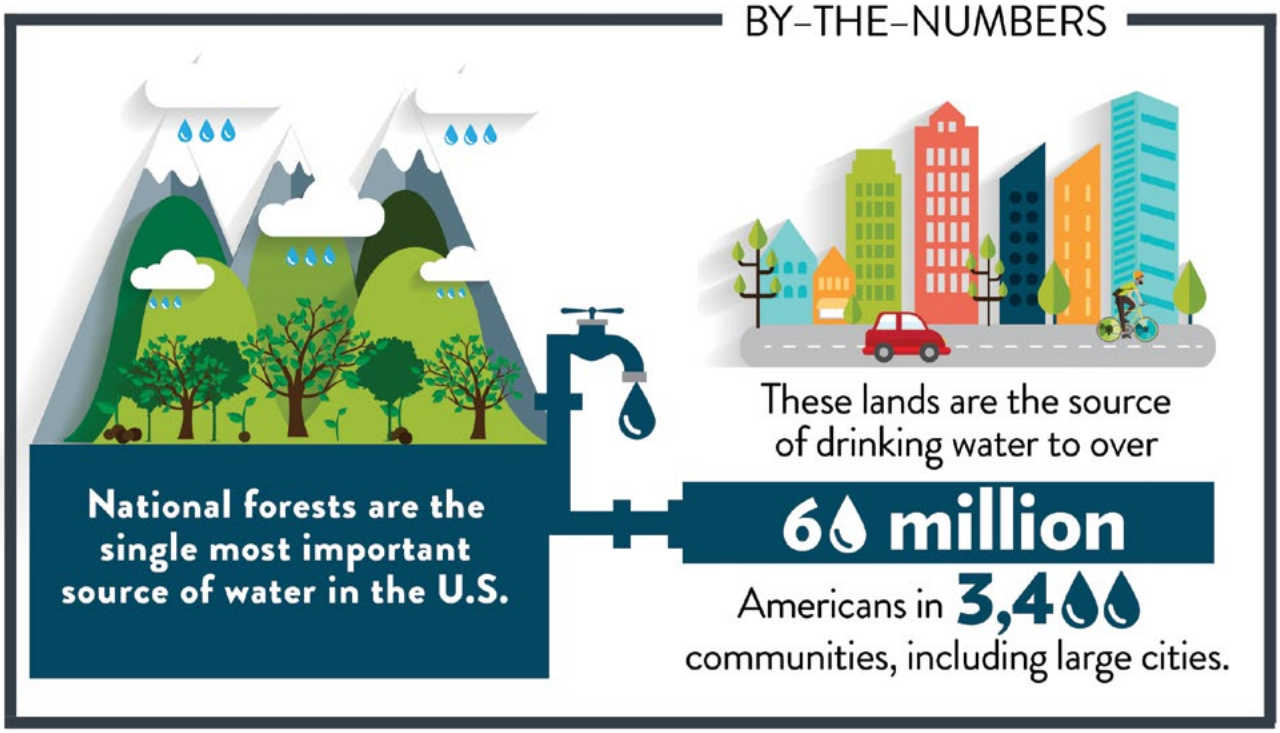
American water utilities spend millions of dollars protecting and improving their sourcewater to ensure the delivery of safe drinking water. Knowing the value of this green infrastructure helps communities and land managers better steward watersheds that provide sourcewater and helps the Forest Service better engage with stakeholders in watershed protection.

A study conducted by the Forest Service and American Water Works Association found that forest cover saves costs for water suppliers by reducing sediment and total organic carbon in drinking water sources.

An example of concentrated flow on a forest road. USDA Forest Service photo.

The U.S. Environmental Protection Agency (EPA) explored the need for additional regulations under the Clean Water Act[1] to make sure forest road runoff did not pollute waterways. The EPA decided that the availability of tools—such as GRAIP and its spinoff, GRAIP-Lite—and institutional programs and rules for road sediment reduction at local, State, and Federal levels was already sufficient and that no further regulations were necessary.

In addition to influencing national policy, GRAIP and GRAIP-Lite promote cost-effective decision making. For example, these tools enable land managers to localize roadwork projects on smaller stretches of roads than would otherwise be necessary and thereby reduce traffic disruptions from such projects.



1 Pub. L. 92–500, 86 Stat. 816. October 18, 1972.

Serving as the World's Wildland Fire Experts

Protecting Homes From Wildfires

Forest Service research by the Rocky Mountain Research Station shows that a home's ignitability during extreme wildland fires depends on the characteristics of the structure and the 100 feet immediately surrounding it, including the presence and types of vegetation and outbuildings.

Forest Service research also shows that—surprisingly—most home destruction from wildland fires is associated with burning embers and low-intensity surface fires, not the big flames of intense wildfires. A shower of firebrands lofted into the air ahead of the wildfire can land on a home or its surroundings and result in its destruction. Property owners can use this information to reduce the risk of structure ignitions during wildfires by clearing small debris around their homes.

A house threatened by forest fire in central Oregon. USDA Forest Service photo.

Explaining How Wildfire "Spreads Like Wildfire"

Large wildfires of increasing frequency and severity threaten local populations and natural resources. Although wildfires have been researched and modeled for decades, until recently no verifiable physical theory of how fire spreads has been available to form the basis for the precise predictions needed to manage fires more effectively and reduce their environmental, economic, ecological, and climate impacts.

In 2015, the Forest Service Missoula Fire Sciences Laboratory received an award for its research in buoyant flame dynamics in wildfire spread. Forest Service researchers discovered that convection—hot gases bursting rapidly forward from the flames and contacting the unburnt fuel—is the primary mode of heat transfer that causes wildfires to spread. Before this discovery, most scientists considered radiation—the heat we feel—to be the key heat transfer mechanism in wildfires. This research will help scientists construct better fire models, which in turn will help firefighters keep people, property, and themselves safer while battling a big blaze.

Where There's Smoke, There's Ire

In 2016 alone, more than 3,000 wildland fires burned more than 1 million acres across Alaska, Washington, and Oregon. Smoke is one of the most visible byproducts of fire and poses a threat to public health. As the number of fires in the wildland-urban interface increases, so too does the need for timely, science-based smoke information on wildland fires.

Pacific Northwest Research Station scientists combined models and data from variables, such as weather, emissions, fuels, and terrain, into an integrated framework known as "BlueSky" that predicts the concentrations and trajectories of smoke.

BlueSky, which was launched in 2002, is now used across the country—regionally and nationally—to support air quality forecasting during wildfires and to plan prescribed burns in ways that reduce accumulated forest fuels. BlueSky is at the core of numerous real-time prediction systems, including the system used by the National Weather Service, which produces the country's official smoke forecast. In addition, BlueSky's high-resolution forecasts are used by State and local public health agencies to help them plan to protect the health of the public and firefighters. These forecasts also support transportation safety; low visibility caused by heavy smoke can make it make dangerous to drive or fly in the affected area.

Fighting Fire With Fire: Prescribed Burns

A prescribed fire is "applied in a skillful manner, under exacting weather conditions, in a definite place, to achieve specific results." The right fire at the right place at the right time reduces hazardous fuels and can reduce the risk or severity of future wildfires. A benefit of prescribed fire over wildfire is that it can be planned, burn conditions can be controlled, and smoke impacts can be minimized.

Firefighter on the Wallowa-Whitman National Forest participates in a prescribed burn. USDA Forest Service photo.

Large areas of the Intermountain West need some type of landscape restoration to change fuel patterns, forest age and forest-density conditions. Restoration often includes fuel treatments, including prescribed fire. The hazards of smoke and the advantages of prescribed fire are explained in "Smoke in a New Era of Fire"—an issue of the reader-friendly publication, "Science Update."

Recent Forest Service research on prescribed fire includes—

- The Rocky Mountain Research Station and Pacific Northwest Research Station completed a landmark study—the Prescribed Fire Combustion and Atmospheric Dynamics Research Experiment, or RxCADRE—that helps predict how wildland fires spread and smoke behaves. These predictions support decision making on wildland firefighting and on prescribed burns by reducing impacts to air quality and soil.
- An updated edition of "The Guide to Prescribed Fire in Southern Ecosystems," which was published by the Southern Research Station in 2016, is designed to help resource managers plan and execute prescribed burns in southern forests and grasslands. This publication reviews the history and ecology of fire, reasons for using prescribed fire in the South, weather and fuel conditions that are key to controlling fire, techniques for meeting burn objectives, and techniques for firing and evaluating burns. It also reviews research aimed at increasing the precision of smoke management, which is particularly important as human populations expand into areas where prescribed burning is needed.

A prescribed burn near Galice, OR. USDA Forest Service photo by Lance Cheung.

Era of Megafires Presentation

The number of megafires—large, severe fires that burn more than 100,000 acres—is increasing. Megafires can destroy or severely damage homes, wildlife habitats, and other natural resources.

To initiate discussions in fire-prone communities and increase public understanding of the science of megafires, Paul Hessburg, an expert on fire ecology based at the Pacific Northwest Research Station, collaborated with North 40 Productions of the Wenatchee Valley Museum and Cultural Center to produce "Era of Megafires." This multimedia presentation describes the inadvertent creation of current wildfire-prone conditions and identifies varied practical strategies that communities, land managers, and homeowners can apply to help reduce the future severity and impacts of wildfires.

"Era of Megafires" has been presented in dozens of cities to tens of thousands of citizens and has been adapted into a TED Talk. In addition to serving as an educational tool, "Era of Megafires"—which uses compelling storytelling techniques and innovative multimedia approaches to translate research on megafires for popular audiences—serves as a model for effective science communication. The "Era of Megafires" TED Talk has, to date, received more than 1 million views.

Dr. Paul Hessburg delivers his "Era of Megafires" presentation. USDA Forest Service photo.

Data for Decision Making on Firefighting

As the world's premiere firefighting agency, the Forest Service develops cutting-edge firefighting resources. These resources include the Wildland Fire Decision Support System (WFDSS) developed at the agency's Missoula Fire Sciences Laboratory in Montana. WFDSS is the primary system used by fire managers and analysts to make strategic and tactical decisions that maximize firefighter safety and minimize community risk to save lives and property.

WFDSS accesses and integrates national weather data and forecasts, fire behavior predictions, economic assessments of values at risk, smoke management assessments, and landscape databases to support decision making. Easy to use and web based, WFDSS is responsive to changing fire conditions. Before development of the WFDSS, planning and decision documentation for fires were conducted using multiple unconnected processes, yielding many limitations.

The Missoula Fire Sciences Laboratory

The internationally renowned Missoula Fire Sciences Laboratory in Missoula, MT, addresses the complicated, dynamic issues associated with wildland fire. The lab's cutting-edge, uniquely applicable wildland fire research advances our understanding of fire and increases the safety and effectiveness of fire, fuel, and smoke management. The lab produced the WFDSS and scientific breakthroughs on flame dynamics and designation of the Home Ignition Zone.

Producing Advanced Wood Products

A Wood Product Stronger Than Steel Could Change the World

Measuring 1 million times less than the width of a human hair, graphene is harder than diamonds and 200 times stronger than steel. Small, strong, and flexible, it is the most conductive material on earth and has the potential to charge a cell phone in 5 seconds or to upload a terabit of data in 1 second. It can be used to filter salt from water, develop bullet-stopping body armor, and create biomicrorobots.

Derived from the same graphite used in pencils and many other common use products, graphene is, ironically, one of the most expensive materials on the planet. That is because the process of chemically peeling off, or exfoliating, a single layer of graphene from graphite ore is cost prohibitive on an industrial scale.

However, a Forest Service team that includes co-owners Mississippi State University and Cooperative Research and Development Agreement partner Domtar Paper Company have developed a more cost-effective way to produce graphene from lignin rather than graphite. Considered a low-value byproduct of the paper-making industry, lignin makes the cell walls of plants rigid and woody but is also an abundant source of renewable carbon. This research led to the filing of two patents and the production of a small quantity of graphene that can be provided to university and industry collaborators for further testing.

The availability of large quantities of graphene will have a huge impact on the development of lighter and stronger structural materials for the automotive, aerospace, and building industries. An airplane with wings made from a graphene-based composite would be lighter and require less fuel. Adobe Stock licensed photo.

Research Helps Fuel Coast-to-Coast Flight

Technology developed by the Forest Products Laboratory enabled a commercial airline to use alternative jet fuel in a coast-to-coast flight in November 2016.

The alternative fuel was made from the postharvest debris that is often burned as waste. It was produced through the efforts of Northwest Advanced Renewables Alliance (NARA), led by Washington State University, using SPORL (that is, sulfite pretreatment to overcome the recalcitrance of lignocelluloses), a technique the Forest Products Laboratory developed for pretreating woody biomass for conversion to aviation fuel.

The demonstration flight from Washington State to Washington, DC, was fueled with a 20-percent blend of sustainable aviation biofuel that is chemically indistinguishable from regular jet fuel. Such fuels can help reduce the industry's carbon footprint and reliance on fossil fuels, create jobs, and bolster economically challenged timber-based rural communities.

The NARA initiative was made possible by a $39.6 million grant from the USDA National Institute of Food and Agriculture to support research on biofuels and biochemicals, foster regional supply chain coalitions, empower rural economic development, and educate the public on the benefits of bioenergy.

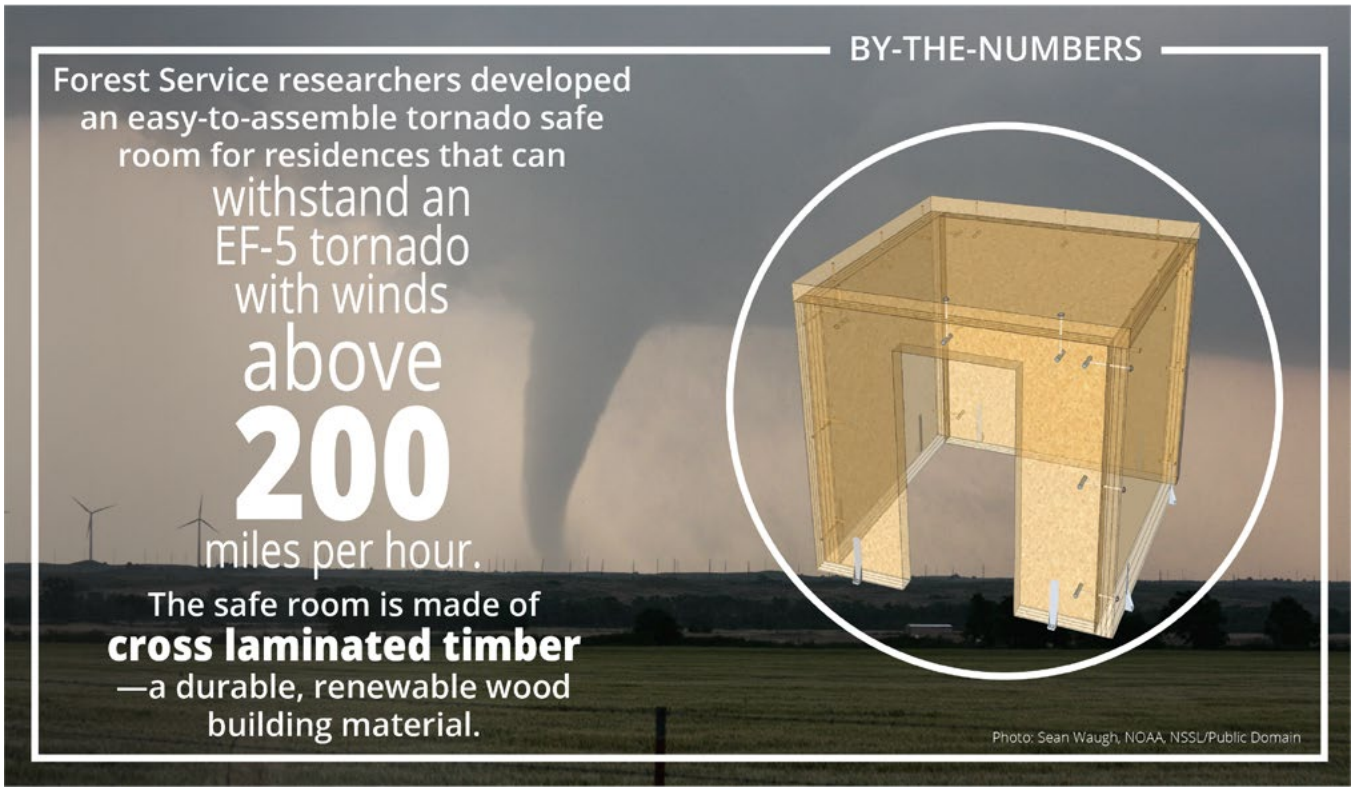
Turning Low-Grade Wood Into High-Value Goods

The Forest Service helps maximize forest resources by identifying new ways to put underused forest materials to work. Thanks to a new technology developed by the Forest Products Laboratory, lower-grade woody material can now be manufactured into glued-laminated, or "glulam," timber. Because glulam is strong and stiff, beams made with it can span long distances without intermediate columns. Structurally sound and aesthetically pleasing, glulam beams are often now incorporated into the construction of churches, sporting arenas, and other large structures.

Development of a Ready-to-Assemble Tornado Safe Room

Cross-laminated timber (CLT) is made from layers of lumber stacked in alternating directions and structural adhesive. CLT's advantages include its light weight, strength, and ease of assembly.

The growth of the market for CLT has made available manufactured wood panels that are ideal for tornado safe rooms and shelters. The thick cross-section of the laminated panels is well suited to resist wind and impact loads produced by tornados.



Stepping up to the Plate for Baseball

Forest Products Laboratory research has led to changes in bat manufacturing processes that increase the safety for baseball players and fans. Major League Baseball funded the research, which showed that (1) the main cause of broken bats is inconsistencies in wood quality, primarily the manufacturing detail *slope of grain*, for all wood species; and (2) low-density maple bats crack and shatter more often than ash or higher density maple bats. The rate of shattered maple bats has decreased more than 50 percent since 2008.

The Forest Service continues to pitch in for baseball by working to stop the spread of the invasive emerald ash borer, which is killing off ash trees—one of the preferred woods used to produce bats.

The Forest Product Laboratory's long-term partnership with Major League Baseball has increased the safety of America's pastime for players and fans alike by reducing the number of shattered bats. iStock licensed photo.

A High-Tech Facility Advances Nanotechnology

In 2012, the Forest Service's Forest Products Laboratory in Madison, WI, unveiled a $1.7 million production facility for renewable, forest-based nanomaterials. This facility is the leading U.S. producer of nanocellulose materials.

Nanocellulose is wood fiber broken down to the nanoscale. (A nanometer is roughly one one-millionth the thickness of a dime.) Nanocellulose-based materials provide high-strength properties with low weight.

The automotive, aerospace, electronics, consumer products, and medical device industries see high potential for these innovative materials. The facility supports the commercialization of these materials by providing researchers and early adopters of the technology with working quantities of forest-based nanomaterials.

Improving Condition of Forests and Grasslands

Science-Based Forest Planning

The 154 national forests and 20 national grasslands in the United States are managed according to forest plans that are based on "the best available science." A new study confirms that much of that "best science" stems from Forest Service research.

Northwest Forest Plan Science Synthesis

The Pacific Northwest and Pacific Southwest Research Stations synthesized science published since 1994 to help inform revision of land management plans for 17 national forests within the 24 million-acre Northwest Forest Plan area. The resulting science synthesis is aimed at informing the assessment stage of forest planning.

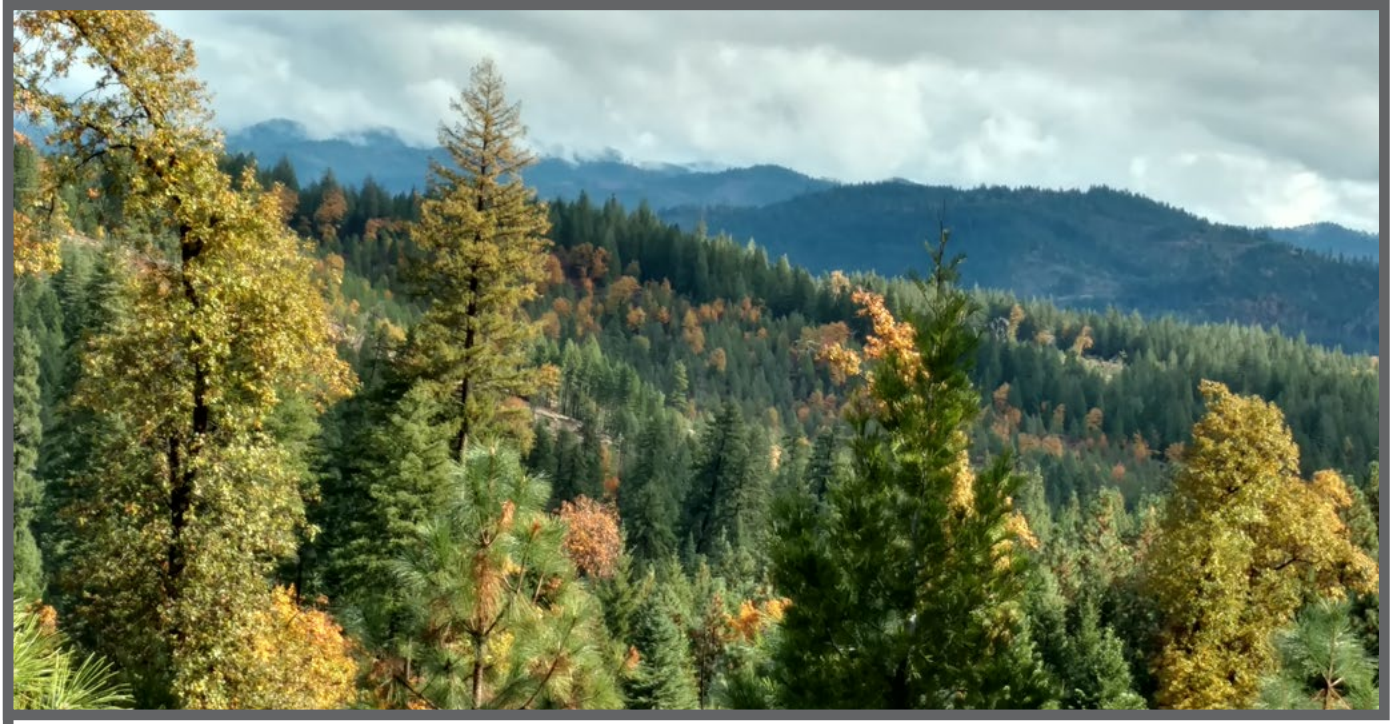
The Sagebrush Science Framework

Where can we best target our limited resources to benefit conservation and restoration of these ecosystems? Addressing such questions requires cross-boundary collaboration. The Sagebrush Science Framework (RMRS-GTR-360 and RMRS-GTR-389) identifies priority areas for conservation and restoration in the

A Network of Living Laboratories

Since 1908, the Forest Service has progressively expanded its system of 80 Experimental Forests and Ranges, which support long-term science and management studies. Such studies yield a wealth of unique records and knowledge of nationwide forest and rangeland ecosystems.

A short video, "Using Experimental Watersheds to Understand the Impacts of Forest Management," explains how research on the Kings River Experimental Watershed in the Sierra National Forest is addressing challenges such as drought, bark beetle infestation, and air pollution.



Fall colors near Trinity Helibase Area. Courtesy photo by Barbara Ramey.

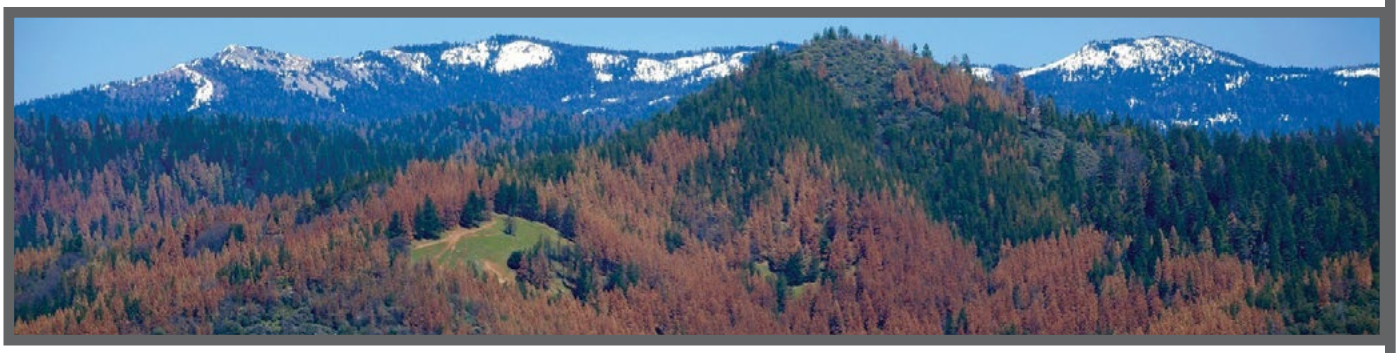
sagebrush biome. Forest Service researchers with the U.S. Department of the Interior Bureau of Land Management, U.S. Fish & Wildlife Service, U.S. Geological Survey, and other State and Federal partners created the two-part framework to provide the credible science basis for decision making, as well as management implications of those decisions.

Ensuring U.S. Forests Are Forever

Forest Service silviculture researchers are world-recognized experts in developing cutting-edge methods for sustainably and cost-effectively growing trees and managing forests that provide vital resources. Through short- and long-term experiments, these researchers have learned how to—

- Plant and care for young forests that have been burned by wildfire.
- Keep forests healthy by giving trees room to grow.
- Produce oak forests that provide wildlife habitat and wood products.
- Grow black cherry trees for crafting beautiful furniture.
- Grow forests that provide lumber for building homes and for producing paper products.
- Innovate computer programs for predicting how forests will grow under changing conditions.

The continued contributions of Forest Service silvicultural researchers will support the conservation and sustainability of U.S. forests for future generations.

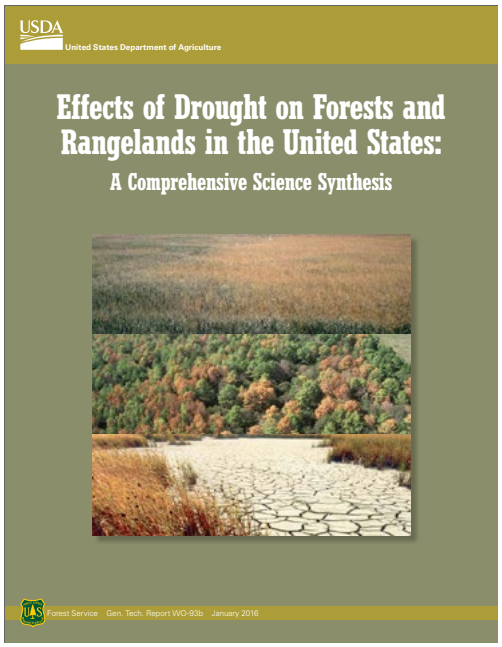


Dead trees on the Sierra National Forest on April 5, 2016. USDA Forest Service photo.

Addressing Massive Tree Mortality in California

Since 2010, an estimated 129 million trees have died in California's national forests due to conditions caused by climate change, unprecedented drought, bark beetle infestation, and high tree densities. Forest Service scientists have been helping land managers and the public understand the phenomenon and develop ways to recover from it.

Each year, researchers produce a tree mortality predictor map that informs land managers where the next round of mortality is most likely to occur and helps them prepare for it. A series of videos explores the ecological conditions triggering the outbreak event, as well as land management strategies for more resilient forests in the future and wildlife implications. Research conducted in experimental forests in mortality zones offers insights on forest structures and densities that increase forest resilience to drought and bark beetle outbreaks. Future research will be aimed at identifying tree species and seed sources that are optimal for reforestation under changing climatic conditions.



Researchers and crew plant bluebunch wheatgrass to test the efficacy of seed transfer zones for improved restoration success at Steens Mountain, OR. USDA Forest Service photo.

Dealing With Drought

In 2016, the Forest Service published "Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis." This report establishes the scientific foundation for managing resiliency and adaptation to drought.

The consequences of drought impacts in the Eastern United States could equal or exceed those in the West. Eastern States have large human populations living near forests and relying on them for many key resources, including clean water and air.

Sowing the Right Seeds for Restoration

Large wildfires are becoming more frequent in the Great Basin, which includes most of Nevada and parts of California, Idaho, Oregon, and Utah. After barren land in the Great Basin burns, restoration efforts must quickly target this burned land to prevent cheatgrass—a highly flammable and invasive plant—from carpeting the ground and fueling more fires.

To support such restoration efforts, Rocky Mountain Research Station scientists identified native plant strains that thrive in arid climates and can block cheatgrass invasions. They showed land managers how to plant the right native seeds in the right places at the right time. As a result, native plant species now account for most seeds used in Great Basin restoration (see "Fighting the Good Fight Against Invading Plants and Pathogens," page 26).

Back to the Future: The Promise of Biochar for Improving Degraded Soils

Biochar is a charcoal product derived from plant matter. Forest Service researchers have applied biochar to restore organic matter to degraded forest, range, and mine soils as part of several restoration projects. They have demonstrated that this remarkable material may increase soil's infiltration and water-holding capacity, thereby decreasing runoff, erosion, and drought impacts and increasing desirable vegetation growth. Biochar also provides promise for improving farmland in Western States, where dry land farming practices are common.

In addition, Forest Service researchers recently patented a modification of an existing technology called the “air curtain burner” that converts piles of slash—cut limbs, treetops, and brush—into a nearly market-ready form of biochar. This modified design enables the burner technology to produce biochar pellets continuously while workers feed slash into the burner, so that the speed and efficiency of biochar production can be increased.

Forest Service research on biochar was inspired by the first known example of the use of biochar, which involved the terra preta soil of the Amazon River Basin. This soil has retained its fertility for thousands of years despite continuous weathering, thanks to the occurrence of charcoal in the soil in the central Amazon Basin in Brazil. Prehistoric natives living in the Amazon Basin created biochar by burning vegetation and putting the resulting black carbon material in the soil. Forest Service researchers saw a direct application for biochar in forest and grassland application.

Biochar made from drought-killed ponderosa pine is added to surviving trees on the Stanislaus National Forest in California to improve soil water-holding capacity and to improve tree health. USDA Forest Service photo.

Restored Southern Forests: The Nation’s Wood Basket

In the 1950s, the Southern United States featured immense acreages of cutover forest and degraded agricultural land. Research by the Forest Service, Southern Research Station, and its partners provided foresters with detailed information on collecting and processing seeds, growing seedlings, and planting practices to successfully reestablish southern pines.

The application of this research has resulted in a restored southern forest landscape, now a principal economic resource. Considered the Nation’s “wood basket,” the region generates more than 55 percent of U.S. production of roundwood, which is timber taken from near the tops of the trees and left as small logs used in furniture production. Loblolly pine is the primary source for wood products.

Today, the Forest Service belongs to the Longleaf Pine Partnership Council, which is working towards a 15-year goal of increasing the area of longleaf pine ecosystems from 3.4 to 8.0 million acres. Longleaf pine forests once covered more than 90 million acres in the Southern United States. These ecosystems are among the world’s most ecologically diverse and home to many plant species found nowhere else.

Southern forests, including longleaf pine ecosystems, are battling threats from invasive insects and pathogens, such as the emerald ash borer and sudden oak death. The survival of Eastern tree species depends on Forest Service research that aims to improve trees’ genetic ability to resist the onslaught of nonnative insects and diseases.

A researcher collects a twig sample from a Douglas-fir tree growing in one of the garden sites in the Douglas-fir Seed-Source Movement Trial. USDA Forest Service photo.

Historic Giants Reveal How Trees Grow Over Time

Douglas-fir trees are towering icons of the Pacific Northwest. Today, nurseries around the world still base their planting practices on research that began in 1909 in the first tree nursery fields in what is now the Wind River Experimental Forest in Washington.

The Forest Service's Pacific Northwest Research Station continues to build on this historic knowledge. The station plants Douglas-firs adapted to particular climactic conditions and altitudes in geographically dispersed study sites characterized by a range of conditions. This research helps forest managers select seed sources for Douglas-firs that are better adapted to changing conditions.

The Nation's Forest Census

The Forest Inventory and Analysis (FIA) program is the continuous U.S. forest census. Every 5 to 10 years, FIA collects measurements from 355,000 field plots and via remote sensing, then uses this data to report on the current status and trends in forest area, species composition, and tree health.

This information supports investment decisions, such as the siting of mills and recreation facilities, the sustainability of management practices, the health and productivity of forested lands, State decision making on actions needed to keep forested land forested, analyses of invasive species, and wildlife modeling.

FIA information also helps project how forests are likely to appear 10 to 50 years from now. Such projections are needed to evaluate the effectiveness of current forest management practices and long-term forest sustainability.

Tree Range Shifts Among *Discover* Magazine's Top 100 Stories of 2017

Published in 2018, Discover magazine's list of the top 100 science stories of 2017 includes a study by Forest Service researchers and partners showing that the ranges of 86 tree species in the Eastern United States are shifting north or west. Researchers attribute these dramatic shifts to changes in temperature and precipitation.

Who Owns U.S. Forests?

Contrary to popular belief, nearly two-thirds of forests in the conterminous United States are privately, not publicly, owned. The distribution of ownership is 43 percent family, 28 percent Federal, 16 percent corporate, 7 percent State, and 4 percent other private land (which includes Native American Tribal ownerships).

By showing the distribution of forest ownership, the Forest Ownership Map of the Conterminous United States developed by the Northern Research Station promotes the development of policies that support the conservation and wise management of public and private forests.

Understanding Forest Disturbances

Disturbances that involve the removal or loss of forest canopy impact the growth, yield, and recovery of forests. An improved understanding of trends in forest disturbances and their impacts is needed to support key forest management decisions.

Landsat images and data from FIA and partners were used to generate annual maps of forest disturbances within the conterminous United States from 1986 to 2010. Known as the North American Forest Dynamics (NAFD) dataset, the maps were published in 2016.

Forest disturbances shown in these maps include (1) major timber harvest areas in the Southeast, the Pacific Northwest, and Maine; (2) extensive mountaintop mining in the southern Appalachians, from western Virginia to Tennessee; (3) substantial hurricane damage on the East Coast; and (4) large-scale damage from fire and insect outbreaks concentrated in the Western United States.

A publicly available peer-reviewed package describes the methods used by the Rocky Mountain Research Station to identify the causes of disturbances shown in the maps.

Seeing the Future of Forests

The Forest Vegetation Simulator is a family of forest growth simulation models used to estimate how forest vegetation will change in response to natural succession; proposed management actions; and disturbances like fire, insects, and disease. It helps resource managers decide how to manage forests to provide the wood, water, wildlife habitat, energy, and other resources we need—even under changing conditions. It is used throughout the United States and in Canada, Europe, and Asia.

Vegging Out: Analyzing Large-Scale Vegetation Changes

Under Forest Service leadership, a U.S. National Vegetation Classification system launched in 2015 to provide the first common language for vegetation classification. Previously, a patchwork of uncoordinated classification systems limited studies to small-scale, local, and individual land ownerships. This new classification supports the landscape-scale analysis needed for land management and other applications, such as defense programs that require information about changes in land cover.

New Northwest Forest Plan Science Synthesis

The Pacific Northwest and Pacific Southwest Research Stations have synthesized science published since 1994 to help inform revision of land management plans for 17 national forests within the 24-million-acre Northwest Forest Plan area. The resulting science synthesis is not a decision document; it only informs the assessment stage of forest planning and, therefore, has no economic impact.

Monitoring and Conserving Wildlife and Fish

eDNA: New Tool for Wildlife Detectives

The Forest Service is pioneering the development and application of environmental DNA, or eDNA, a sensitive new technology that can detect the presence of threatened and endangered species in ecosystems and of individuals at the leading edges of invasive species takeovers.

An eDNA analysis uses filtered water samples to detect trace amounts of cells shed by organisms to detect the presence of a species of interest. The Forest Service has developed a field-proven eDNA sampling protocol that requires only 15 minutes of effort by a single person to collect a sample. These noninvasive tests can be conducted more effectively and at a fraction of the cost of traditional methods.

Accurate inventories can help communities avoid the large costs associated with managing the ecological impacts of uncontrolled species invasions. For example, New England spends over $800,000 per year on managing aquatic invasive species; Maine estimates that future infestation control costs could exceed $2 to $4 million per year for the State alone.

Kellie Carim fills a sample for eDNA sampling. USDA Forest Service photo.

BY-THE-NUMBERS

Environmental DNA (eDNA) tests can detect free floating DNA in soil, water or air to help determine if a species of interest is present in an ecosystem.

These species include bull trout, grizzly bear, coho salmon and harlequin duck. Tests with eDNA, which are noninvasive, are much faster, cheaper and more sensitive than invasive tests.

In 2015 and 2016, Rocky Mountain Research Station scientists used eDNA to identify the distribution of invasive brook trout and threatened bull trout in selected areas of the Rocky Mountains. Bull trout is a culturally significant species to several Tribes in the Northwest and Columbia River Basin, a prized game fish, and a potential consideration in land management decisions.

In 2017, Forest Service researchers published an article titled, "eDNA—Not Just for Fisheries Biologists Anymore."

Spotted Owl Habitat Preferences

Because of the sensitive nature of spotted owl populations, forests in the Western United States have been managed to protect spotted owl habitat under the premise that the owls require expanses of dense canopy cover. A new study of forest attributes along California's Sierra Nevada, however,

A spotted owl on a branch. USDA Forest Service photo by Justin Windsor.

showed that tree canopy height, not density, best predicts spotted owl habitat. Results from this study may help relieve land managers of some concern over creating canopy gaps and enable them to more effectively manage forest densities for wildfire and drought resistance. This study used airborne technology that provides a top-down view on the forest canopy and is believed to be the largest spotted owl study in terms of area analyzed.

This study comes on the heels of a new report—"The California Spotted Owl: Current State of Knowledge"—synthesizing the last two decades of research on spotted owls.

Improving Sage-Grouse Habitat

The greater sage-grouse is a striking bird that needs large areas of healthy sagebrush to survive. Forest Service research helped keep the greater sage-grouse off the endangered species list. A decision to list the greater-sage-grouse would potentially have impacted many valuable economic activities across 173 million acres of sage-grouse habitat. Healthy sagebrush habitat supports $1 billion in outdoor recreation alone. The decision not to list the greater sage-grouse follows an unprecedented conservation partnership supported by Rocky Mountain Research Station scientists that has significantly reduced threats to the greater sage-grouse and its ecosystems across 90 percent of the species' breeding habitat in the Western United States.

Many species that live in the sagebrush ecosystem live nowhere else in the world. Protecting the sage-grouse's habitat also protects the 350-plus other species, including elk and golden eagles, that depend upon the sagebrush landscape for survival.

Greater sage-grouse. USDA Forest Service photo.

Battling for Bats

As voracious consumers of insect pests, bats reduce the pesticide bill of the U.S. agricultural industry by over $23 billion annually. White-nose syndrome (WNS), however, has killed more than 6 million bats since 2006 and currently threatens the survival of 7 bat species. Forest Service researchers co-led a genetic study that tracked the origins of the WNS fungus to North America, rather than Eurasia.

The severity and potential ecosystem-level effects of WNS in North America make it one of the most serious wildlife diseases ever recorded.

A little brown bat infected with white-nose syndrome. Photo courtesy of the New York State Department of Environmental Conservation.

Northern Research Station researchers and partners recently developed the first successful treatment for WNS. In 2015, this treatment enabled a group of sick bats to recover enough to be released back to their natural habitat. The treatment involves using native soil bacteria to produce a natural compound that diffuses into the air and inhibits growth of the fungus that causes WNS.

Although this treatment holds great promise, it is still in the developmental phase. Researchers continue to study its effectiveness and are working to develop an efficient delivery mechanism that can be safely used outside controlled conditions.

In related research, in 2018, a team of scientists from the Forest Service and the University of New Hampshire published a study showing that the fungus that causes WNS is highly sensitive to ultraviolet light. Any weakness of the fungus may be good news to managers trying to develop treatment strategies.

Underpasses Benefit Wildlife and People

About 200 people are killed annually in the United States in as many as 2 million wildlife-vehicle collisions, at a cost of more than $8 billion. Studies have shown, however, that well-placed wildlife crossings coupled with fencing can reduce wildlife-vehicle collisions by 75 to 100 percent.

The Pacific Southwest Research Station, along with collaborators, thus broke ground in 2016 on two wildlife underpasses along Highway 89 in California. Built to near-identical dimensions only 1 mile apart, the underpasses will be unique, enabling scientists to manipulate conditions to learn what factors, such as sound levels or ground coverage within the tunnels, might attract wildlife.

Illegal Marijuana Growing: Not a Victimless Crime

In 2011, the Forest Service reported illegal marijuana grow sites on 67 national forests in 20 States. Researchers have documented an increasing threat to wildlife from large quantities of pesticides, such as DDT, and other chemicals used on trespass marijuana sites on public and Tribal lands. Wildlife die by consuming these chemicals or by eating contaminated prey. Impacted species include game, raptors, and the fisher—a small mammal that is an indicator species for forest management and a candidate for endangered species protection.

Anticoagulant rodenticides found near an illegal marijuana cultivation site on the Sierra National Forest. USDA Forest Service photo.

In 2017, Pacific Southwest Research Station researchers co-authored an article summarizing the ways in which illegal marijuana grow sites harm wildlife, cause ecological problems such as soil and water contamination, and threaten public safety. This work supports the development of remediation techniques and decision making by land managers, law enforcement, policymakers, and conservation groups.

Conserving Wildlife Around the World

Over the past decade, the Forest Service has developed a suite of landscape modeling tools to explore how ecological changes caused by human activities affect species occurrence, population sizes, and movement. The Rocky Mountain Research Station initially used these tools to research the impacts of overpass and highway construction on bears and martens, research that led to the construction of more animal-friendly structures.

An adult male lion in the Central Kalahari Game Reserve in Botswana. USDA Forest Service photo.

Now the Forest Service's tools and expertise are in worldwide demand. For example, a 2015 study showed that lions in the Kavango-Zambezi Transfrontier Conservation Area of Africa were vulnerable to habitat fragmentation, but strategically placed fencing and wildlife corridors may provide a viable solution. The agency's landscape modeling methods and expertise have also informed conservation issues involving clouded leopards in Borneo, elephants in India, snow leopards in central Asia, and brown bears in Europe.

Keeping Wildlife Populations Connected

As the human population grows, habitat corridors become critical for keeping wildlife species connected across landscapes. A 2016 computer-based technique introduced by the Rocky Mountain Research Station could help conservation biologists choose the most cost-effective ways to connect populations of rare, threatened, and endangered species in protected areas.

Researchers tracked wolverines and grizzly bears in Montana to demonstrate the feasibility of using this new technique to identify optimal multiple-species corridors, offering significant cost savings. This technique demonstrated the potential benefit of creating connections between protected areas that cover a range of scales, such as the reevaluations of local easement options to the development of national strategies.

Solved! Mystery of Long Lonely Cougar Journey

In 2011, a wild cougar killed on a Connecticut highway received a significant amount of national media attention. Based on DNA and photo analysis, the Rocky Mountain Research Station proposed that the cougar had traveled alone for 1,600 miles, from the Black Hills of South Dakota, because he could not find a female anywhere along his route. The documentation of such a rare biological event—which marks the longest documented distance traveled by this species—shows the great dispersal potential for male cougars and highlights scientists' ability to detect such movements with verifiable DNA and photo records.

Cougar on a fallen tree. iStock licensed photo.

Fighting the Good Fight Against Invading Plants and Pathogens

Discerning the Role of Roads in Driving Forest Plant Invasions

Some invasive species thrive on disturbances from road construction—but farms and other human activities benefit invasive species even more, according to a Forest Service study that earned an Editor's Choice honor in the March 2018 issue of the journal "Diversity and Distributions." The study incorporated data from the FIA program.

Results of the study show that the risk of forest plant invasions cannot be evaluated only on the basis of distance from a road—and that context is key. These results can help managers develop regional strategies to control or eradicate invasive plants. They also demonstrate the value of the FIA program for answering nontraditional forest inventory questions.

The Hapgood Pond Recreation Area on the Green Mountain National Forest. USDA photo.

Addressing Trouble in Paradise: Tree Death in Hawaii

'Ōhi'a is the most common tree species in Hawaii's native forests, growing from sea level to nearly 8,000 feet. This tree species also has significant cultural values to the Hawaiian people. 'Ōhi'a, however, is dying off on Hawaii's Big Island.

In 2015, researchers from the Forest Service, Institute of Pacific Islands Forestry, USDA Agricultural Resources Service, and University of Hawaii identified the culprit for the die-off. The fungus *Ceratocystis fimbriata* clogs a tree's vascular system with its spore-producing machinery, quickly killing it by depriving it of water. The exact origin of the fungus is unknown, but it is not native to Hawaii.

Although no cure currently exists for the deadly fungal disease, Pacific Southwest Research Station scientists are educating land managers and others about disease prevention strategies to confine it to the Big Island.

‘Ōhi’a, *Metrosideros polymorpha.* Photo courtesy of Kim Starr.

Bugs Stopped at the Border

Over many decades, international trade has inadvertently introduced numerous nonnative wood-feeding pests and plant pathogens into the United States. Some of these insects are highly invasive and have caused serious environmental and economic impacts.

For example, the emerald ash borer has killed hundreds of millions of ash trees in 25 States since arriving from Asia, most likely in packing materials, in the 1990s. Land managers spend tens of millions of dollars per year to combat the beetles.

A new international standard for wood packaging material, however, is slowing the inadvertent imports into the United States of invasive bark- and wood-boring insects. According to a study conducted by Forest Service Northern Research Station scientists and their collaborators, the new standard resulted in an infestation drop of 52 percent.

Emerald ash borer feeding on an ash leaf. Photo courtesy of Leah Bauer.

The Bane of Weed Management: Secondary Invasions

Exotic plant invasions present a worldwide threat to natural ecosystems and cost the global economy hundreds of billions of dollars annually. Although targeted efforts to suppress invasive plants are costly, their effectiveness remains unclear. Forest Service Rocky Mountain Research Station scientists and their partners examined one factor inhibiting ecosystem recovery, secondary invasion by nontarget exotics, to quantify the magnitude of the problem and identify treatment strategies.

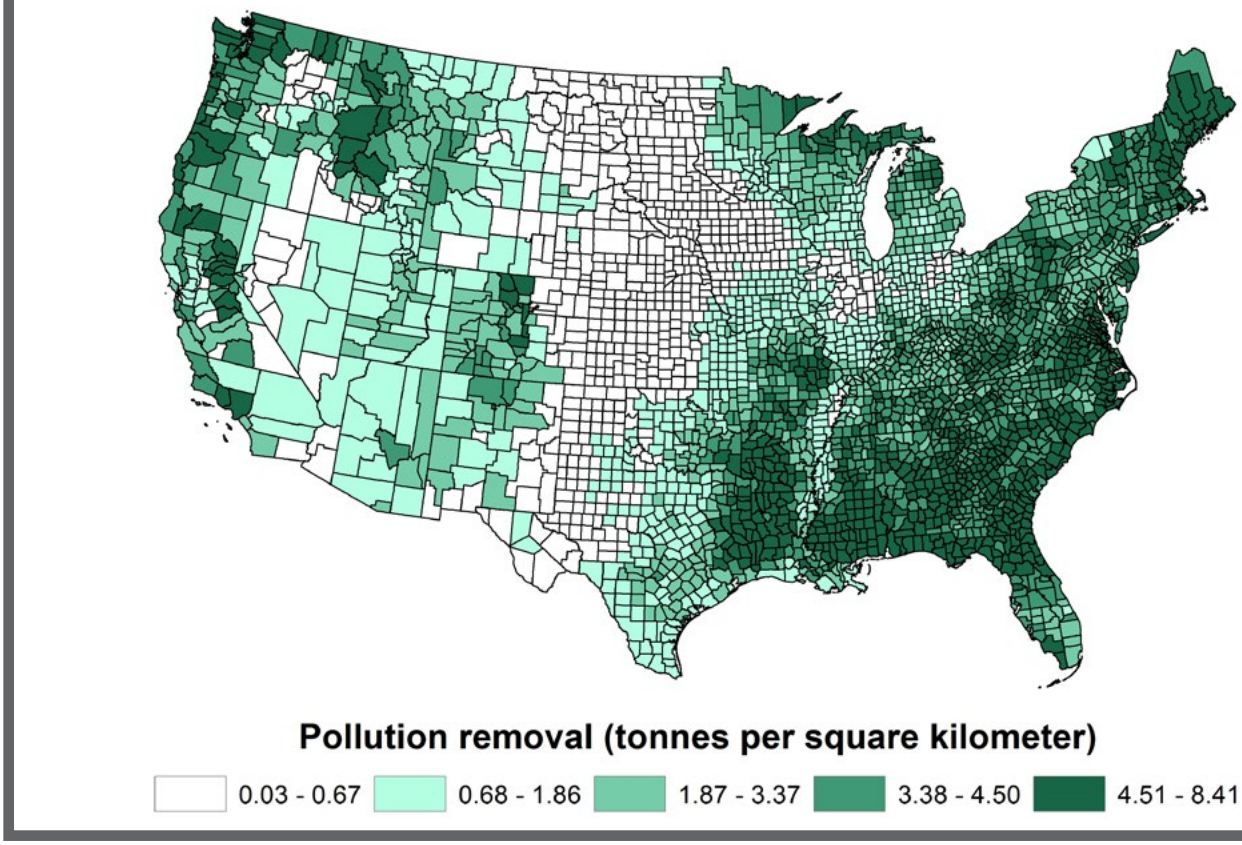
Often, targeted efforts to suppress invasive plants are followed by a secondary invasion by other pest plants. In fact, the more successful the suppression of target invaders, the greater the response of secondary invaders. Addressing this problem requires management strategies that anticipate and suppress secondary invaders while rapidly restoring native plants to fill the space vacated by the targeted invader. Accomplishing the latter requires improved revegetation techniques.

Promoting Human Health

Trees Save Lives

In the first broad-scale estimate of air pollution removal by trees nationwide, the Forest Service Northern Research Station and its collaborators calculated that trees annually save more than 850 human lives and prevent 670,000 incidences of acute respiratory symptoms.

The researchers valued the human health effects of pollution that trees removed from the air at nearly $7 billion per year.



This map shows estimated removal, per square kilometer of land, of all air pollutants (nitrogen oxide, ozone, particles with a diameter of 2.5 micrometers or less, and sulfur dioxide) by trees per county in 2010.

The study is unique in directly linking the removal of air pollution with improved human health and associated health values. The scientists found that pollution removal is substantially higher in rural areas than urban areas, but the effects on human health are much greater in urban areas. This research underscores the importance of the Nation's urban forests for the more than 80 percent of Americans living in urban areas.

Of Moss and Men: Using Moss As a Bioindicator May Revolutionize Air Quality Monitoring

Localized urban air pollution is not necessarily detected by traditional air quality monitoring. Because one monitor typically costs $50,000, and multiple monitors are usually needed, municipalities generally do not invest in them. Urban air quality monitoring, however, could be revolutionized by a Forest Service Pacific Northwest Research Station study showing that moss, which is plentiful, can be used to detect air pollution, including cancer-causing heavy metals.

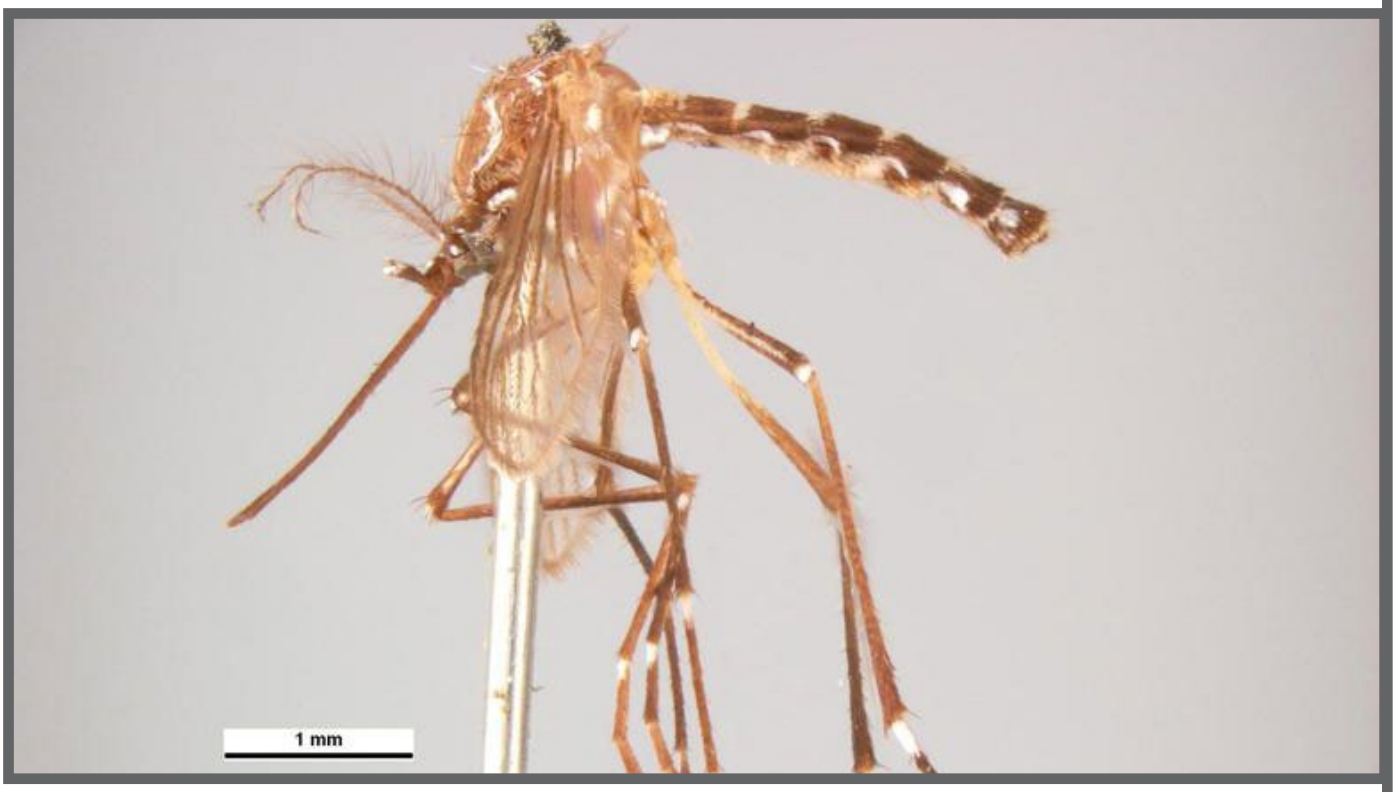
A scientist gathers a moss sample from a neighborhood tree in Portland, OR. Because moss lacks roots, these plants absorb all their water and nutrients from the atmosphere. In so doing, they capture and then store whatever compounds are in the air. USDA Forest Service photo.

The study involved testing moss samples from 346 sites around Portland, OR, for heavy metals in 2013. Based on this testing, which traditional air quality monitoring corroborated, scientists were able to identify previously unknown hotspots of cadmium and arsenic; both are linked to health problems, including cancer. In response, businesses voluntarily stopped emitting cadmium and arsenic, and the State created a new program to increase air monitoring.

The total cost of the Portland study was about $100,000, and each moss-monitoring site cost $50. By contrast, it would have cost about $17 million per year to cover the Portland moss-sampling grid with traditional air quality instruments. Cincinnati, Seattle, and other cities are now interested in using moss-based air quality monitoring.

"Don't Bug Me"

Pacific Northwest Research Station scientists have discovered that certain natural compounds produced by trees can repel mosquitoes, ticks, and fleas better than many widely used synthetic pesticides. Because these pests can carry diseases like the Zika virus and Lyme disease, this discovery could have big public health implications. This research has already resulted in further research by the Centers for Disease Control and Prevention and a license for commercial development.



The Zika virus is mostly spread by *Aedes* species of mosquitoes. Photo courtesy of ForestryImages.org.

Impacts of Urban Forests on West Nile Virus

A study published by Forest Service Southern Research Station researchers in 2016 suggests that forest cover and composition may play a critical role in influencing human risk to West Nile virus. Conducted in Atlanta, the study indicated that mosquitoes carrying the virus are less common in large forested areas. The presence of pine trees in urban forests was also related to lower risk. The amount of impervious surface was associated with increased West Nile virus risks. Urbanization can inadvertently create mosquito habitat as mosquitoes lay their eggs in puddles, rain gutters, and any standing water they find.

Identifying Ebola Hotspots

Among the countries hit by the recent Ebola outbreak was Liberia, where 84 percent of the population lives on the equivalent of $1.25 a day. A 2015 Forest Service Southern Research Station study identified Ebola vulnerability hotspots based on data that incorporated social factors, such as illiteracy, substandard housing, access to medical care, and clean water.

These hotspots corresponded to several districts that showed the highest levels of Ebola infections. This study may guide further research on social vulnerability to disease and help focus investments for addressing future epidemics. The innovative study technique can be adapted to other disease outbreaks that call for rapid, quantitative social vulnerability assessments at multiple scales.

Taking It to the Streets: Urban Forestry

California "Street Tree" Benefits Valued at $1 Billion

Streets lined with gold? Not exactly, but a Forest Service Pacific Southwest Research Station study published in 2016 estimates that trees lining California streets and boulevards provide benefits to municipalities and residents worth more than $1 billion.

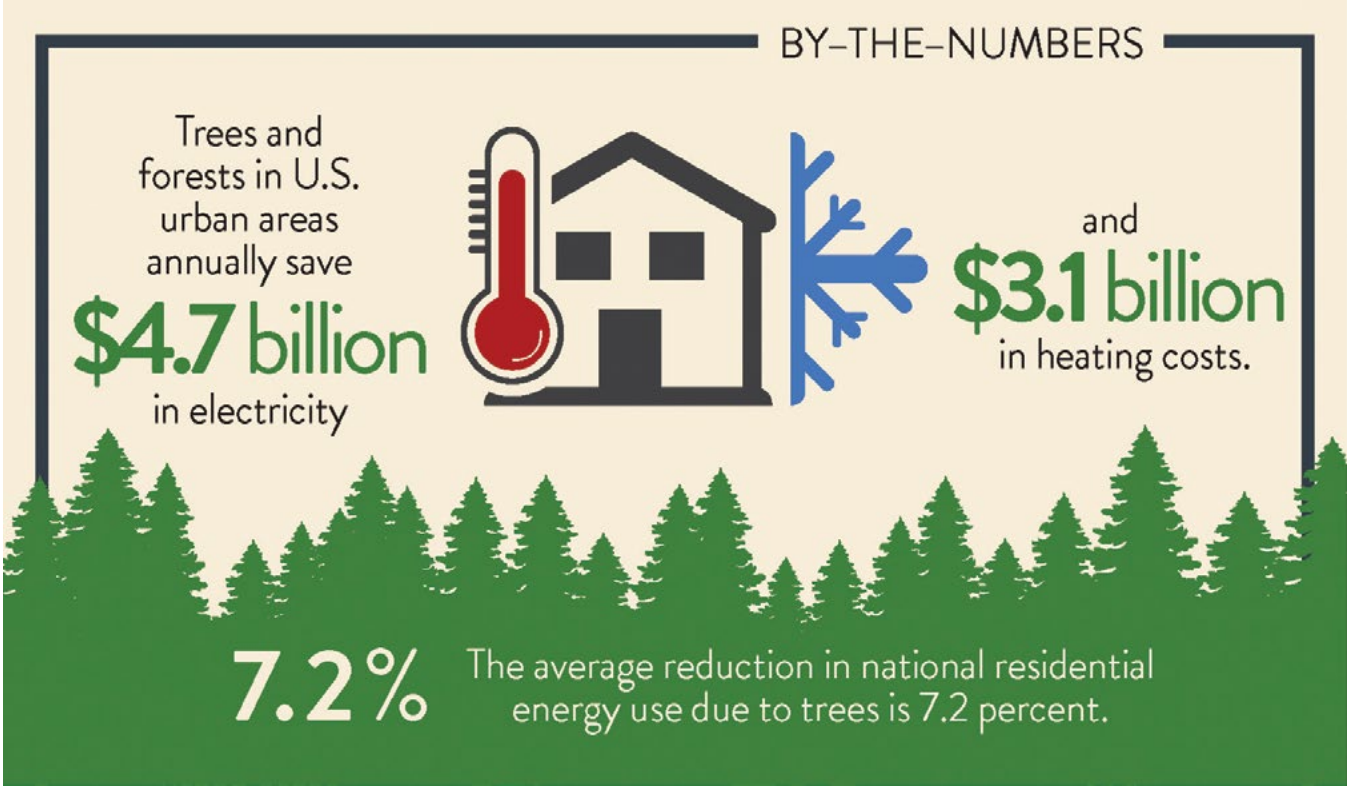
From carbon storage ($10.32 million) and removal of air pollutants ($18.15 million), to interception of rainfall ($41.5 million) and energy savings from both heating and cooling ($101.15 million), California's street trees are paying big dividends. They even bolster property values and home sale prices to the tune of nearly $840 million. The study also highlights trends and tree demographics, information that may help guide urban foresters to decide what trees to plant and where to plant them.

San Francisco trees. Photo courtesy of iStock.

Trees Reduce Building Energy Use in Cities

Urban trees and forests alter building energy use and associated power plant emissions by shading buildings, cooling air temperatures, and altering windspeeds around buildings. Research published in 2017 by Northern Research Station scientists and partners revealed that trees are responsible for an average reduction in national residential energy of 7.2 percent. Trees and forests in urban and community areas in the conterminous United States annually reduce electricity use by 38.8 million MWh (megawatt hours; $4.7 billion), heating use by 246 million MMBtus (million British Thermal Units; $3.1 billion), and avoid thousands of tons of pollutant emissions (valued at $3.9 billion per year).

This research can help give State and national decision makers a better understanding of the benefits of trees and their value to communities. With more than 80 percent of Americans living in urban areas, this research underscores how important urban forests are to people across the Nation.



Going Local: A Place-Based Approach to Reducing Urban Gun Violence

Scientists at the Forest Service Northern Research Station and elsewhere are studying connections between urban greening, public health, and crime. One recent study found that improvements to abandoned buildings and vacant lots have reduced the frequency of firearm assaults. Another study found that the likelihood of gun assault was lower when people were under tree cover as opposed to when they were out in the open. Neighborhood improvements have a lower average financial cost than the gun-related crime that the improvements helped to prevent.

Because many U.S. cities have plans in place to increase citywide tree canopy levels and improve green stormwater infrastructure, Forest Service research may help city land managers to prioritize spending and work with nongovernmental organizations to maximize environmental, economic, and social benefits.

Austin, TX, Helps Launch Urban Forest Inventory

In response to legislative direction in the 2014 Farm Bill,[1] the Forest Service's FIA program initiated an inventory of urban forests to include in its nationwide forest census. Published in 2016, the first urban forest inventory in the country based on urban FIA data was conducted in Austin, TX.

This study estimated the compensatory value of Austin's trees at $16.0 billion and also showed that, per year, Austin's trees store about 1.9 million tons of carbon (a service valued at $242 million); remove about 92,000 tons of carbon (a service valued at $11.6 million); remove about 1,253 tons of air pollution (a service valued at $2.8 million); and reduce annual residential energy costs by $18.9 million.

This information may support urban forest management and planning programs to improve environmental quality and human health. Survey data for Austin and other cities that have since joined the urban FIA program are available online at My City's Trees, an application that enables users to access urban FIA data and produce custom analyses and reports.

1 Pub. L. 113–79, 128 Stat. 649. February 7, 2014.

Urban Forests Manage Stormwater Runoff

Forests efficiently store stormwater, return water to the atmosphere, and filter pollutants from runoff. After reviewing current research on trees and the urban water cycle, Forest Service Southern Research Station scientists developed a way to quickly estimate tree impacts on stormwater when planning engineered systems. By providing the basis for Best Management Practices for urban and suburban projects, this information can help stormwater professionals include urban forest systems in stormwater management projects.

Contributing International Expertise

Tropical Forests Are a "Disturbing" Topic

Effectively managing tropical forests in the face of global climate and land use changes requires understanding the mechanisms that drive functions in varied ecosystems. Based on long-term studies in the Luquillo Experimental Forest in Puerto Rico, Forest Service International Institute of Tropical Forestry researchers and their collaborators documented the high resilience of wildlife populations, plant communities, and biogeochemical cycles to episodic disturbances such as hurricanes.

A simulated forest canopy opening in the Luquillo Experimental Forest to mimic hurricane disturbance and investigate changes in microclimate, biota, and ecosystem processes. USDA National Wildlife Research Center photo by Aaron B. Shiels.

They also identified habitats and wildlife species that are particularly sensitive to hurricane effects. This information can help improve the effectiveness of management prescriptions and guide efforts to design reserves that better mitigate the impacts of hurricanes, including 2017 Hurricane Maria which caused catastrophic damage to sensitive wildlife species and ecosystems and resulted in numerous fatalities across the northwestern Caribbean.

Crime Scene Investigation-Like Techniques Used to Combat Timber Smuggling

The Forest Service Forest Products Laboratory has applied its expertise in forensic botany to many international crime-busting efforts. For example, in 2014, the Forest Service analyzed specimens of a $7 million cache of rosewood timber seized by Sri Lankan officials to determine if the wood was an endangered or legal variety. The analysis showed that the anatomy of the seized wood was consistent with that of known species of rosewood from Madagascar, home to many unique rosewood species and the source of huge volumes of smuggled wood. These results compelled Sri Lanka to pull the wood from the market.

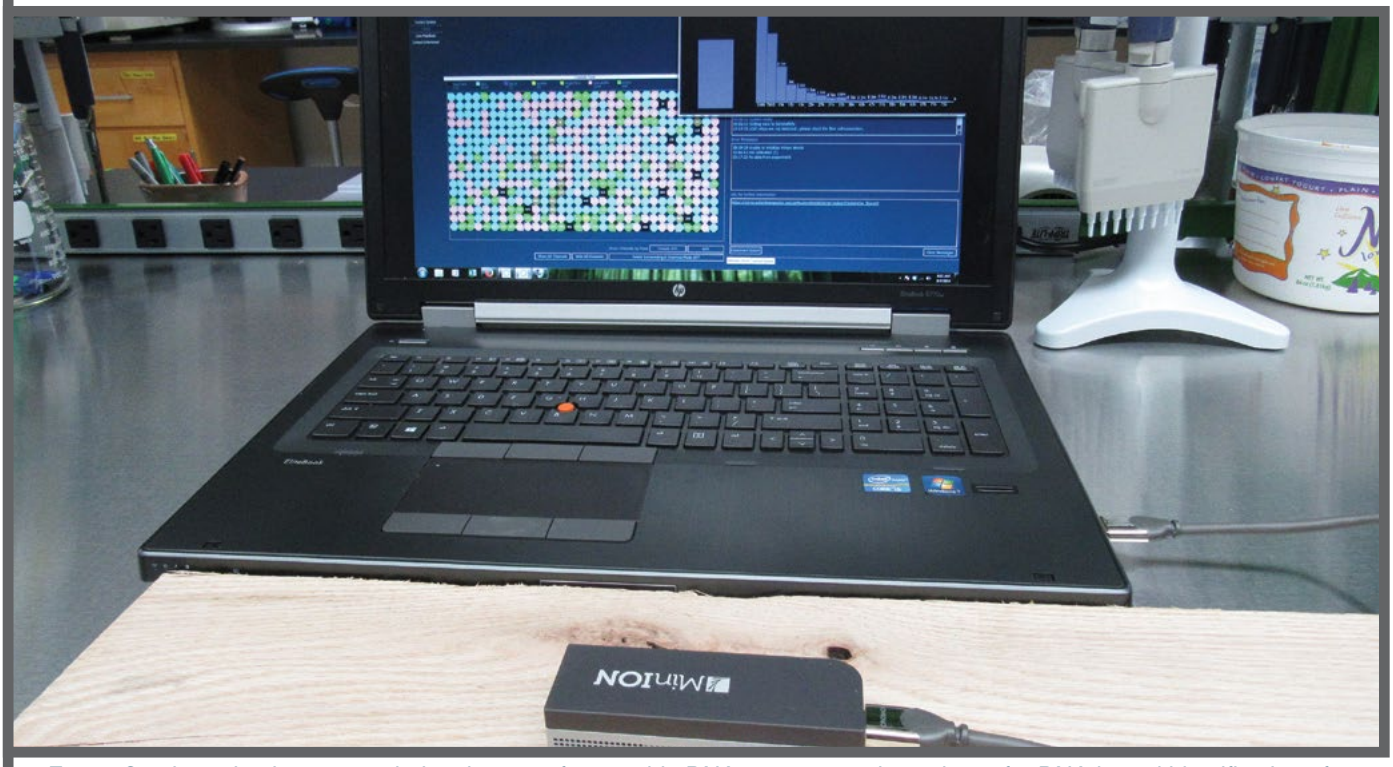
The black market in timber contributes to deforestation and has been associated by the international law enforcement community with human trafficking, illegal wildlife trafficking, drug trafficking, and other types of illegal syndicates.

Crime scene tape wrapped around forest trees. iStock licensed photo.

DNA Research Combats Illegal Logging

International illegal logging costs governments and the private sector $10 to $15 billion in losses. Up to 10 percent of U.S. imported wood products are derived from illegally logged trees. Visually indistinguishable from the white oak species of Europe and North America, Mongolian oak is often harvested illegally in the Russian far east. This illegal activity degrades the habitat of the endangered Siberian tiger and reduces the value of legal white oak wood.

To address this problem, the Forest Service scientists from the Pacific Northwest Research Station, along with U.S. and international partners, identified DNA markers that determine the continental origin of white oak wood products. These markers enable importers to distinguish the origin of white oak and avoid illegally harvested wood. Researchers are working to develop field-based testing to enable companies, consumers, and regulators to evaluate all parts of their wood supply chain, even in remote locations.



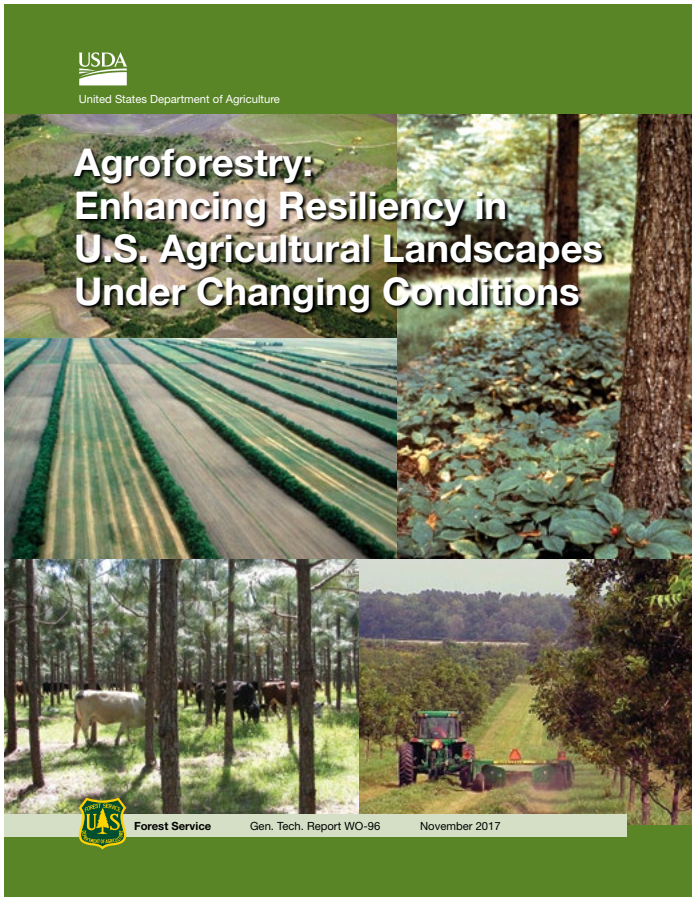
Forest Service scientists are exploring the use of a portable DNA sequencer, shown here, for DNA-based identification of plants and plant pathogens. Driven by a laptop, this sequencer generated a run of Oregon white oak DNA. USDA Forest Service photo by Rich Cronn.

Mixing It Up With Agroforestry

The Advantages of Agroforestry: A Science-Based Synthesis

Agroforestry—the intentional integration of trees and shrubs into crop and livestock production systems— is a strategy that can enhance the resiliency as well as the productivity and profitability of agricultural operations and lands.

In 2018, USDA Forest Service published "Agroforestry: Enhancing Resiliency in U.S. Agricultural Landscapes Under Changing Conditions." A first-ever synthesis on agroforestry as a mechanism for improving the resiliency of farm lands, this report can help farmers, decision makers, and researchers develop integrated agricultural strategies and production systems.



Agroforestry practices like windbreaks and alley cropping—in which trees or shrubs are grown around or among crops—can reduce wind velocity, decrease erosion, and improve soil health. Silvopasture, which is the sustainable production of livestock, trees, and cattle on the same unit of land, allows trees to be managed for timber or other tree crops while providing shade and shelter for livestock. Riparian buffers—vegetated areas along streams and other water bodies—stabilize banks, reduce nutrient runoff, and provide shade that helps keep rising stream temperatures in check. Forest farming, or the cultivation of high-value crops like ginseng or shitake mushrooms under a forest canopy, is an agroforestry tool used to diversify farm portfolios and provide economic stability for landowners.

According to the report, well-designed agroforestry systems increase per-land-unit area productivity and can increase crop yields as much as 56 percent. These practices also support key nature-based benefits such as crop pollination, biological pest control, and habitat connectivity.

Big Benefits From Buffers

Riparian forest buffers are strips of vegetation (usually a combination of trees, shrubs, and other perennial plants) planted along streams, lakes, or wetlands. These buffers filter pesticides, animal waste, and sediment from agricultural runoff; stabilize eroding banks; and provide shade, shelter, and food for fish and other aquatic organisms. Buffers can also provide edible, herbal, medicinal, or decorative products for people.

The National Agroforestry Center (NAC) produces software, models, and guidance documents to help private and public landowners meet their individual business and conservation goals using riparian buffers and other agroforestry practices.

For example, one NAC tool enables land managers to compare the potential income they would generate by planting a buffer versus a crop alternative. Another tool helps land managers design buffers that are wider along banks where pollution inputs are higher. Such variable-width buffers can more effectively and cost-efficiently trap pollutants than can standard, uniform-width buffers.

A riparian buffer lines a waterway. USDA National Agroforestry Center photo.

Planning for Extreme Ecosystem Disturbance

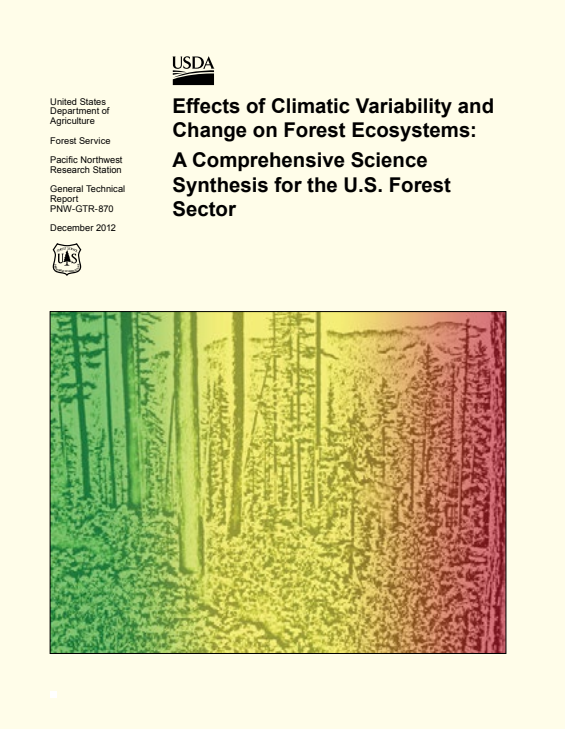
Counting Carbon

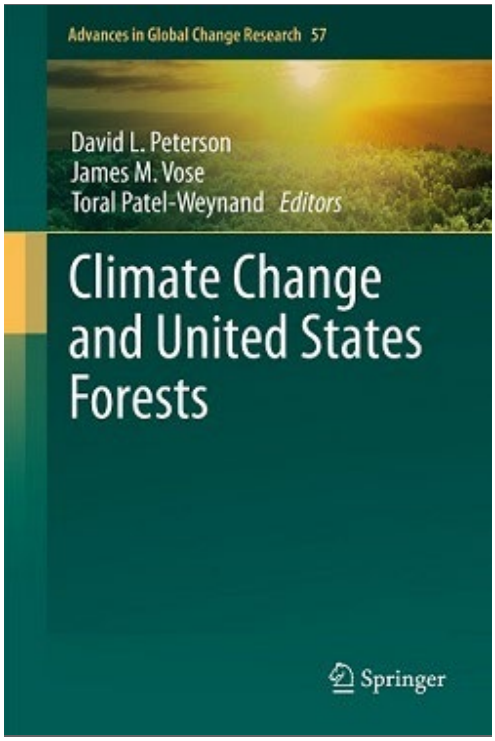
Annual monitoring of forest carbon is critical to meeting the information needs of forest managers and policymakers. In 2015, the Forest Service Northern Research Station developed a new approach to U.S. forest carbon accounting—the Forest Carbon Accounting Framework (FCAF). This approach incorporates the most consistently measured annual inventories of U.S. forests and thereby reduces inconsistencies inherent in previously used approaches. Therefore, FCAF produces a more accurate picture of how much carbon is sequestered in U.S. forests and the impacts on carbon sequestration of changes in land use, wildfire, and invasive insects.

Synthesizing the Science of Extreme Environmental Disturbance

Published in 2013, "Effects of Climatic Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector," is a scientific assessment of the current condition and likely future condition of U.S. forest resources relative to weather variability and events. It includes descriptions of key regional issues and examples of a risk-based framework for assessing the effects of extreme weather. Contributors include more than 55 experts from the Federal Government, including USDA agencies, as well as State agencies and universities.

"Climate Change and United States Forests" followed up "Effects of Climatic Variability and Change on Forest Ecosystems." Edited by Forest Service researchers, this book provides resource managers, researchers, and the public with a comprehensive science-based assessment of the effects of extreme weather on U.S. forests. *Choice* magazine named "Climate Change and United States Forests" one of the Outstanding Academic Titles of the year in 2015.





Recreation

Tools Supporting Recreation

Forest Service researchers are producing state-of-the-art tools to help accommodate recreational activities, such as equestrian rides, backpacking, and water sports. These tools include Human Ecology Mapping, which helps managers identify where important user areas exist, overlap, and potentially conflict. This tool supports planning for sustainability and balancing multiple uses.

R&D also developed the National Visitor Use Monitoring System, which is an interactive, user-friendly computer model used to predict the number of visitors to popular wilderness areas. This system helps managers set quotas for wilderness permits to help ease congestion.

How Much Fun? Evaluating Economic Implications of Recreation on National Forests

The number of people participating in outdoor recreation is projected to increase through 2030. A recent Forest Service study indicates that people made more than 891 million visits to recreate on Federal lands in 2016; these people spent $49 billion and supported 826,000 jobs with these visits. These findings may contribute to evaluations of outdoor recreation trends and projections of future participation. They may also be incorporated into forest assessments, planning, and National Environmental Policy Act applications.

Stay Informed of the Latest Forest Service Research and Technology

Forest Service R&D Newsletter

The Washington Office (WO) of Forest Service R&D publishes a reader-friendly monthly online newsletter, which has more than 10,000 subscribers. Each issue features concise summaries of study results, reports, and new projects that can help land managers more effectively maintain public and private forests and grasslands, as well as blogs and articles on timely topics. Access the latest issue and subscribe to the newsletter on the home page of the WO R&D.

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