United States
Department of
Agriculture

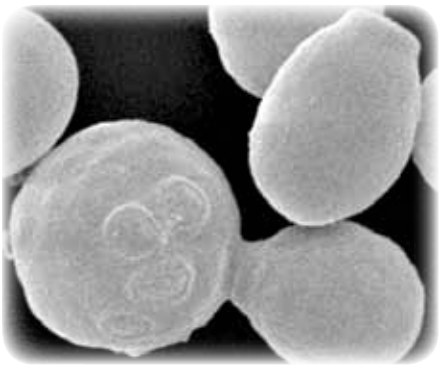
Forest Service

FS–973

March 2011

USDA Forest Service
Research & Development
2010 Highlights

Science Serving Society



Welcome From the Deputy Chief

I'm honored to have been selected as Deputy Chief of Research and Development (R&D) for the Forest Service, an agency of the U.S. Department of Agriculture (USDA), and a world leader in innovative science for sustaining global forest resources for future generations. Our research benefits the owners and managers of rural and urban forests and farms and helps link environmental health with community well-being. We employ approximately 500 scientists and hundreds of technical and support staff in a range of biological, physical, and social science fields. Our scientists work on programs in all 50 States, U.S. territories, and commonwealths and collaborate on research with scientists at the international level.

Forest Service researchers, like their colleagues in the rest of the agency, go to work every day with the motto "caring for the land and serving people" in their heads and their hearts. As the new leader of this dedicated cadre of scientists, I am committed to working hard to deliver the information and solutions needed to sustain our Nation's forests and rangelands and the values they provide for the American people.

I can't think of a better time to assume leadership of Forest Service R&D. Former Deputy Chief Ann Bartuska made great strides in elevating the status of our work, and 2011 is also the 100-year anniversary of The Weeks Act, which sets the stage for the establishment of national forests and experimental forests. The latter are living laboratories where Forest Service scientists not only learn but also share results with research cooperators and stakeholders. Long-term research records on many of these lands date back to the 1930s, when 29 of the 81 experimental forests and ranges were established. Today, they provide an opportunity to conduct research on some of the biggest topics of the day, including global climate change, watershed function, invasive plants, and recovery from natural disturbances such as hurricanes or wildland fires.

As the historic programs continue, a litany of environmental threats continues to adversely impact our Nation's forests and grasslands. Be they bark beetles or termites, invasive plants and animals or diseases, degraded river systems, or the impacts of climate change, Forest Service scientists will continue to produce pertinent information and tools necessary to meet the challenge of managing and protecting our Nation's varied and evolving landscapes. All of the work we do has a steady focus on informing policy and land management decisions and improving the lives of the citizens of this country.

U.S. Department of Agriculture Secretary Tom Vilsack's all-lands approach to forest management looks beyond humanmade boundaries to emphasize the importance of collaborative partnerships with States and public and private partners to conserve and restore our Nation's forest lands. With that paradigm in mind, researchers at the Forest Service and other USDA agencies are sharing knowledge and resources with partners in academia, industry, other government entities, and nongovernmental organizations (commonly referred to as NGOs). USDA and its agencies are working across ownerships to tackle the serious environmental challenges facing our Nation.

Climate change is certainly one challenge that knows no boundaries. The Forest Service Global Climate Change Research Strategy is guiding climate change research nationally and assisting public and private landowners who need knowledge to manage under the uncertainty of a changing climate. The strategy is making it possible for us to inform our cooperators and stakeholders on how to mitigate the effects of climate change and adapt their management practices accordingly. As part of the strategy, Forest Service scientists have developed tools and delivered science to those in need of them. Several of our most successful inventions and research projects related to climate change are highlighted in this report.

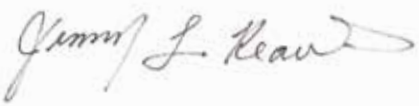
Another major issue of concern is water. Climate change has the potential to reduce water levels in some regions. Forest Service researchers are looking for ways to enhance the health of our watersheds and, in turn, enhance water quantity and quality. Most of the water we drink comes from forested watersheds, so maintaining abundant supplies of clean water is critical to Americans, as well as to wildlife populations and their habitats.

Our Nation's prosperity—and particularly the prosperity of our rural communities—is closely linked to the health of our lands and natural resources. Simply put, a healthy environment brings good jobs and income opportunities to rural America. Research is the key to protecting, achieving, or restoring healthy forests and grasslands. Research also leads us to new scientific frontiers such the nanotechnology program underway at the Forest Products Laboratory in Madison, WI. Nanotechnology-enabled revenue streams will create forest sector

economic growth, new jobs, and new opportunities for skilled workers. The streams will use forest-based materials we can grow, transport, and convert into value-added products in the United States more efficiently than nearly anywhere else in the world. Bioenergy is another growing program for Forest Service scientists in Madison and elsewhere. As the Nation looks for viable alternatives to fossil fuels, the Forest Service is working to demonstrate how wood can help meet some of our energy needs.

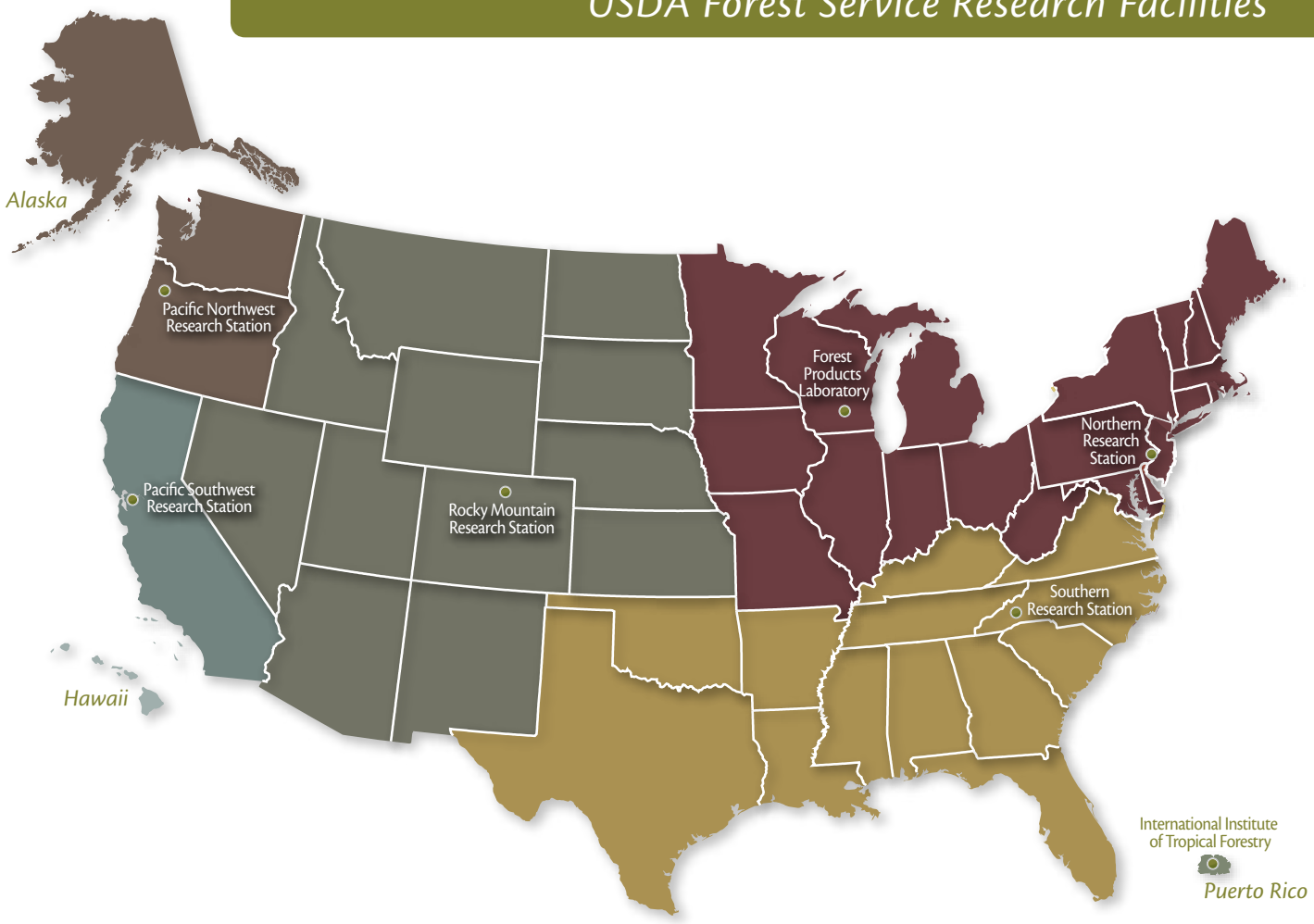
Knowledge is only useful if it reaches the people who need it most. We are working hard to make sure our research results, innovative technologies, and new products are placed in the hands of people who can use the tools or information and apply it to the ground, problem, or situation that cries out for remedy.

Lastly, in all that we do, we must do it safely. Forest Service leadership recently re-dedicated its efforts to provide a safe working environment for all of its employees. As the new deputy chief of R&D, I wholeheartedly embrace a culture of safety and will do everything in my power to give R&D employees the training and tools they need to be safe at work. After all, our most important resource is our people.



Jimmy L. Reaves
Deputy Chief of Research and Development

USDA Forest Service Research Facilities



(*U.S. Pacific Island Territories Not Pictured*)




Contents




Forest Service Research and Development

Introduction

The research and development (R&D) arm of the U.S. Department of Agriculture (USDA), Forest Service, works at the forefront of science to improve the health and use of our Nation's forests and grasslands. Research has been part of the Forest Service mission since the agency's inception in 1905. Today, some 500-plus Forest Service researchers work in a range of biological, physical, and social science fields to promote sustainable management of the Nation's diverse forests and rangelands. Their research covers a lot of territory, with programs in all 50 States, U.S. territories, and commonwealths. The work has a steady focus on informing policy and land-management decisions, whether it addresses invasive insects, degraded river ecosystems, or sustainable ways to harvest forest products. The researchers work independently and with a range of partners, including other agencies, academia, nonprofit groups, and industry. The information and technology produced through basic and applied science programs is available to the public for its benefit and use.

Forest Service R&D organizes research under seven Strategic Program Areas (SPAs), which support an integrated approach to the study of broad, complex environmental and social issues. Within this structure, researchers address the Forest Service strategic goals and objectives at the watershed, landscape, regional, and national levels to focus research on the large-scale problems of national concern identified in the *USDA Forest Service Strategic Plan: FY 2007–2012*. SPAs provide consistent and stable, nationally strategic subdivisions of the national Forest Service research program for purposes of program development; management of review and oversight; communication to national audiences, including national interest organizations, the Administration, Congress, and the general public; budget formulation and presentation; and integration and collaboration among research stations and between stations and external partners.

Wildland Fire and Fuels

The **Wildland Fire and Fuels** SPA provides the knowledge and tools needed to help reduce the negative impacts and enhance the beneficial effects of wildland fire on society and the environment. It focuses on understanding and modeling fundamental fire processes, interactions of fire with ecosystems and the environment, and social and economic aspects of fire; evaluating integrated management strategies and disturbance interactions; and applying fire research to management problems.

Southwestern Ponderosa Pine Fire Findings Published

▲ Fire-scarred pine snags within oak patches suggest a historical fire regime that included both surface and stand-replacing fires. Tree-ring analyses show that this and other pine trees in this area were killed by a fire in 1867. *Jose Iniguez, Forest Service*

In 2010, the Rocky Mountain Research Station published groundbreaking findings on fire behavior in southwestern ponderosa pine forests. Using tree-ring data, researchers were able to reconstruct forest fire regimes back to 1495. This historical perspective showed that certain ponderosa pine–oak forests had both surface fires and stand-replacing fires. Stand-replacing fires, occurring on steep slopes, were found to often fragment the continuity of flammable fuels and subsequently lead to longer fire intervals (up to 50 years longer between fires). This new information gives land managers greater understanding of how and when to introduce prescribed fire and manage lighting-ignited fires. This will have implications for restoration efforts and management decision-making. A fire ecologist for Saguaro National Park, where much of this research was conducted, offered the following perspective: "This information has been very valuable to us in this section of the park. The research shows that we should expect and should allow for some intense fire there. It is also important to have this scientific data to inform our decisions as we look to manage fire and park resources, including the threatened Mexican spotted owl."

Lead: Rocky Mountain Research Station

▲ Oak patches created by a stand-replacing fire in 1867 are still evident across the Rincon Peak landscape today. *Jose Iniguez, Forest Service*

Designing Fuel Treatments for the Wildland–Urban Interface

Research findings in an area of vacation homes near Idaho's Warm Lake are helping resource managers design fuel treatments for the wildland–urban interface. In 2007, the Cascade Complex of fires burned upward of 200,000 hectares in central Idaho. Fire went around and through 3,200 hectares of fuel treatments (a combination of prescribed fire and mechanical treatments) intended to change fire behavior and, thus, provided a degree of fire protection for more than 70 vacation homes on leased national forest land. At the request of the Boise National Forest, the Rocky Mountain Research Station studied effects of those treatments. Although they did not stop fires or slow their spread, the treatments did limit severity and made it possible for crews to put out spot fires as they approached homes. No dwellings burned. Researchers also found that treated areas tended to have more post-fire green vegetation than did areas not treated. In

addition to its influence on treatment planning for the wildland–urban interface, this research has also led to information useful in maintaining wildlife habitat, protecting soil productivity, and speeding recovery of vegetation

Lead: Rocky Mountain Research Station

▲ Fire moves through a fuels-treated area in central Idaho. *Mark Loseke, Forest Service*

Broadening Information Available to Managers of Wildland Fires

Researchers from the Rocky Mountain Research Station worked with colleagues on both sides of the country to develop a tool that gives wildland fire managers detailed air-quality information. The tool enhances use of the web-based Wildland Fire Decision Support System (WFDSS). Managers use WFDSS for assistance in making strategic and tactical fire suppression and management decisions. Users can access this tool via the Internet, using the air-quality portal, and can enter a few parameters to help them get results that evaluate smoke concentrations, smoke dispersal, particulate levels, and more. One potential result is creating smoke dispersal models that can be used to anticipate long-term impacts of heavy smoke in a specific community. Decisionmakers may then use that information as they consider how to proceed in managing a fire. Work to refine the tool is ongoing. The Rocky Mountain Research Station collaborated with the Pacific Northwest Research Station and with the Forest Service Fire and Aviation Management Staff in Washington, DC, to create this tool.

Lead: Rocky Mountain Research Station

BioSum Evaluates Bioenergy Production Sites and Assesses Economic Feasibility of Fuel Treatments

Increasingly large and severe wildfires threaten millions of forested hectares throughout the West. Under certain conditions, mechanical thinning can address these hazardous conditions while providing opportunities to obtain wood products and create renewable energy from the removed biomass. To help identify these opportunities, Pacific Northwest Research Station scientists created an analysis framework called BioSum that uses the nationwide Forest Inventory and Analysis (FIA) database and allows forest managers to simultaneously assess the effectiveness of fuel treatments, identify locations and capacities of processing facilities, and project returns on investments. For example, BioSum assessments of treatments to reduce fire hazard in southern Oregon and northern California found fuel treatments that included removal of trees larger than 25 centimeters in diameter, more effectively reduced fire hazard, and were more economical than treatments focused only on smaller trees. A number of external groups have also used BioSum. These include the city of Lakeview, OR, to support biomass plant capacity decisions; the California Department of Forestry to evaluate forest practices policy options; and organizations in Arizona and New Mexico in planning and to attract bioenergy investment capital.

▲ Mechanical thinning is one way to reduce crown fire hazard while providing opportunities to create renewable energy. *Jeremy Fried, Forest Service*

Lead: Pacific Northwest Research Station

Wildland Fire and Fuels

Advancing Understanding of Atmospheric Interactions With Wildfires

The environment surrounding wildfires can be dangerous for firefighters and those in surrounding areas because of erratic fire behavior. Smoke from fires can also worsen local and regional air quality. The manner in which fires spread and smoke is transported from fires depends, to a large degree, on ambient air turbulence (wind gusts) and turbulence generated by the fires. Through partnerships with San Jose State University, Michigan State University, and the Silas Little Experimental Forest, modeling and experimental research have led to an improved understanding of how air turbulence can affect wildfires and smoke in different regions of the United States. A new atmospheric-turbulence-based fire-weather index has been developed for potential inclusion in operational fire-weather forecasts. This index can be used to anticipate when weather conditions could lead to erratic fire behavior because of strong wind gusts. Each day, fire managers can view 24- to 48-hour predictions of this index through the Fire Consortia for Advanced Modeling of Meteorology and Smoke—Eastern Area Modeling Consortium Web site (http://www.nrs.fs.fed.us/eamc) and through the Predictive Services branch of the Interagency Eastern Area Coordination Center. A complete description of the index was published in 2010 in the *International Journal of Wildland Fire*.

Lead: Northern Research Station

▲ Fire spread and smoke transport through forest vegetation, as shown in this photograph of a prescribed burn in the New Jersey Pine Barrens, can be influenced by atmospheric turbulence (wind gusts). *Warren Heilman, Forest Service*

▲ Mixed conifer forest at the Teakettle Experiment Forest after a fuels reduction treatment. *Forest Service*

Research Determines Carbon Costs and Benefits of Fuels Treatments

Nearly a century of fire suppression has increased tree densities and fuel accumulations in the forests in the Western United States. In forests that were historically maintained by frequent, low-severity fire, fire suppression has increased the risk of high-severity wildfire. Forest managers are widely implementing fuel treatments to reduce this risk and restore forests to a more open, fire-resistant structure. As with all management activities, they evaluate such treatments for a range of goods and services provided by forests and rangelands—one of which is carbon sequestration. These treatments carry a near-term carbon cost because standing tree biomass is reduced to lower the risk of future high-severity fire. Treatments aimed at reducing this risk often employ thinning or prescribed burning, or both, to reduce tree density and surface fuel loads. Several carbon costs are associated with these treatments, including increased carbon emissions from prescribed fire, thinning residue, and milling waste; the treatment's consumption of fossil fuels; and a reduction in carbon stocks. Effective treatments, however, lower the risk of large carbon loss from high-severity fire and can increase available resources for leave trees, accelerating growth and carbon sequestration. In an ongoing study at the Teakettle Experimental Forest, the Pacific Southwest Research Station and Northern Arizona University researchers quantified the carbon consequences of different levels of thinning and burning treatments immediately and 7 years posttreatment. They found that carbon stocks were reduced and

Wildland Fire and Fuels

emissions increased with increasing treatment intensity. Although removing larger trees in overstory thinning treatments increased fire resistance, carbon cost was substantially higher. Seven years following treatment, tree growth in all treatments had re-sequestered some of the carbon removed or emitted during treatment implementation. From measured growth rates, they estimated that understory thin and burn treatments will re-sequester all the carbon removed and emitted during treatment in as few as 15 years after treatment, whereas overstory thinning treatments will continue to have net negative carbon balance for many more years because of the removal of many large trees.

Lead: Pacific Southwest Research Station

Invasive Species

The **Invasive Species** SPA provides the scientific information, methods, and technology to reduce, minimize, or eliminate the introduction, establishment, spread, and impact of invasive species and to restore ecosystems affected by the species. This research 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.

Assessing Nonnative Invasive Species

The Forest Service's Southern Region Task Force for Assessing Nonnative Invasive Species (NNIS) was assembled to prioritize NNIS that pose the highest threats to forest and grassland ecosystems in the South. The task force collaboratively compiled a list (based on multiple existing databases and surveys of Forest Service regional staff) of the most potentially damaging species. Existing risk assessments for these NNIS were assembled for ranking priority threats. Through this process, three databases were compiled of NNIS that damage, or have the potential to damage, forest interiors, margins, openings, roadsides, waterways, and wetlands, as well as grasslands and special embedded habitats. These three databases, hosted by the Center for Invasive Species and Ecosystem Health at the University of Georgia, are accessible on the Web (http://www.invasive.org/south/). The Web site has received nearly 26,000 hits since its public release at the beginning of 2010, a figure that suggests strong public interest in the issue of managing invasive species.

Lead: Southern Research Station

▲ Cogongrass infestation in a pine plantation. *Chris Evans, courtesy of Bugwood (http://www.bugwood.org)*

Invasive Species

U.S. Invasive Plants Identified in Comprehensive Database

Scientists at the Eastern Forest Environmental Threat Assessment Center, Southern Research Station, are developing a database of the more than 4,000 plants that have been introduced into the United States. The database compiles a variety of biological traits that affect species invasiveness and distribution. The data will help in developing early warning systems, predictive models, risk assessments, and management plans for invasive plants. The goal is to post the database online for land managers, scientists, and policymakers to use as a comprehensive resource.

Lead: Southern Research Station

▲ Berries of oriental bittersweet (*Celastrus orbiculatus*), a nonnative vine that has invaded southern forests. *Jim Miller, Forest Service*

How Removal of Invasive Trees Affects Nesting Birds in Riparian Areas

In central New Mexico's Middle Rio Grande corridor, birds such as the black-chinned hummingbird and the endangered willow flycatcher nest in invasive exotic tree species. This dependency on otherwise undesirable invasives raised concern about removing these exotic trees for wildfire control. Would nesting be harmed? Researchers from the Rocky Mountain Research Station investigated this question at the request of the U.S. Fish and Wildlife Service, the Middle Rio Grande Conservancy District, and the City of Albuquerque. Researchers studied nesting success in areas dominated by native tree species such as willows, areas dominated by invasive species such as tamarisk, sites that burned, those not burned, and those where invasive species had been removed. Results of this ongoing research indicate that when invasive exotic tree species are removed,

▲ Black-chinned hummingbird chicks in nest. *Forest Service*

riparian-nesting birds move into native trees and nest survival rates show little change. If these invasive species are not removed and the woodland burns, these invasives respond positively to fire and may replace native tree species that are important for nesting by woodpeckers and hawks and for a broad range of other species. This research helps managers make better decisions regarding the management of invasive species. Additional research collaborators include the University of Oklahoma and Gila National Forest.

Lead: Rocky Mountain Research Station

Monitoring of Invasive Tree Takes Flight Over Ohio Forests

Ailanthus altissima (commonly called tree-of-heaven, but perhaps more aptly named stink tree), a rapidly growing nonnative invasive tree, is spreading into many forested landscapes in the Eastern United States and displacing native plants. Because female trees are prolific seeders (350,000 seeds per tree per year) and the prominent seed clusters persist during the winter months, Northern Research Station researchers and partners at the Ohio

▲ Abundant and prominent seed clusters on female ailanthus trees persist through the winter. *Joanne Rebbeck, Forest Service*

Department of Natural Resources, Division of Forestry, were able to develop aerial mapping techniques for finding ailanthus infestations. Using digital sketch mapping technology, they mapped several Ohio State forests by helicopter. The georeferenced coordinates from these surveys were down-loaded to hand-held global positioning system units and used by field crews to find and treat ailanthus trees with herbicides. Aerial surveys were expanded to the growing season, and both male and female trees were mapped on more than 18,000 hectares in six Ohio State forests. This technique has been very successful, providing forest managers with a cost-effective ($0.60 to $1.25 per hectare) and efficient tool to monitor and treat invasive plants across large forested landscapes. Plans are underway to expand aerial ailanthus mapping on the Wayne National Forest.

Lead: Northern Research Station

Trap to Detect Asian Longhorned Beetles

Development of an operationally effective trap has been a goal of the Asian longhorned beetle (ALB) eradication program since the first individual ALB was found in New York in 1996. A trap that can demonstrate the presence of ALBs in an area is critical to detecting and eliminating infestations. A trap that is capable of detecting ALBs at low densities in quarantine zones can also provide positive confirmation of successful eradication. Part of an interagency and university effort, the Northern Research Station helped develop traps for ALBs. In 2009, researchers hung traps in trees in Worcester, MA, in areas where infested trees were still suspected to exist. These traps caught female ALBs when baited with male-produced pheromones alone or in combination with plant volatiles. In 2010, researchers deployed the traps in both the Worcester, MA, and Brooklyn/Queens, NY, infestations to assist in pinpointing lingering ALB populations and in combination with fungal bands for an attract-and-kill strategy led by researchers from Cornell University. In the future, researchers could also deploy traps in high-risk areas in other States to detect new infestations. Research partners include Pennsylvania State University, USDA Agricultural Research Service, USDA Animal and Plant Health Inspection Service, Asian Longhorned Beetle Eradication Program, Massachusetts State Department of Environmental Protection, and Beijing Forestry University.

▲ Female Asian longhorned beetle found in trap in Worcester, MA. *Melody Keena, Forest Service*

Lead: Northern Research Station

▲ Team checking an ALB trap for beetles in Worcester, MA. *Melody Keena, Forest Service*

Effective Treatments for Eradication of Sudden Oak Death Pathogen in Nursery Soils

The sudden oak death pathogen, *Phytophthora ramorum*, infects rhododendron, camellia, and other popular horticultural plants. Nurseries under regulation are inspected before being allowed to ship plants. If the pathogen is detected, they are required to eradicate the pathogen. Despite application of federally mandated eradication treatments, the pathogen persists in soil in some nurseries and reemerges to infect nursery stock. Researchers at the University of California–Davis, funded by a grant from Pacific Southwest Research Station competitive Sudden Oak Death Research Program, determined that several registered fumigants and heat treatments are effective for eradication in nursery soils. This work provides

Invasive Species

growers with greater flexibility and reliability as they attempt to treat nursery areas infested with *P. ramorum* and is being used throughout the U.S. nursery industry as part of the USDA Animal and Plant Health Inspection Service's Confirmed Nursery Protocol. By reducing the likelihood for spread of *P. ramorum* through nursery stock, this project prevents pathogen transfer to uninfested areas.

Lead: Pacific Southwest Research Station

▲ Symptoms of sudden oak death pathogen on camellia. *Canadian Food Inspection Agency*

Outdoor Recreation

The **Outdoor Recreation** SPA is directed at understanding and managing outdoor environments, activities, and experiences that connect people with the natural world. Research within this SPA develops the knowledge and tools to support informed recreation and wilderness management decisions that improve outdoor recreation opportunities for current and future generations while sustaining healthy ecosystems.

Catalyzing Human Behavior in Support of Monitoring Recreation Impacts on Wildlife

Surprising successes have been achieved in the first year of a pilot project examining how humans, lynx, and wolverines use winter recreation areas. This year, hundreds of winter recreationists in Colorado and Idaho agreed to carry global positioning system (GPS) units supplied and monitored by Rocky Mountain Research Station to track their movements. These movements were mapped along with GPS coordinates taken from collars worn by lynx and wolverines to create a unique set of spatial and temporal data that will help tell the story of how lynx and wolverines respond to people recreating in their habitat. Do these animals shift their habitat use to avoid humans? Do they avoid recreation areas altogether, or perhaps during certain times of day when human use is highest? This project uniquely collects the same data across the same geographic scale, using the same technology for both humans and animals on the same landscape. With this information, winter recreation specialists and wildlife biologists will be able to inform the development management actions that can benefit both the wildlife and the recreationists.

Lead: Rocky Mountain Research Station

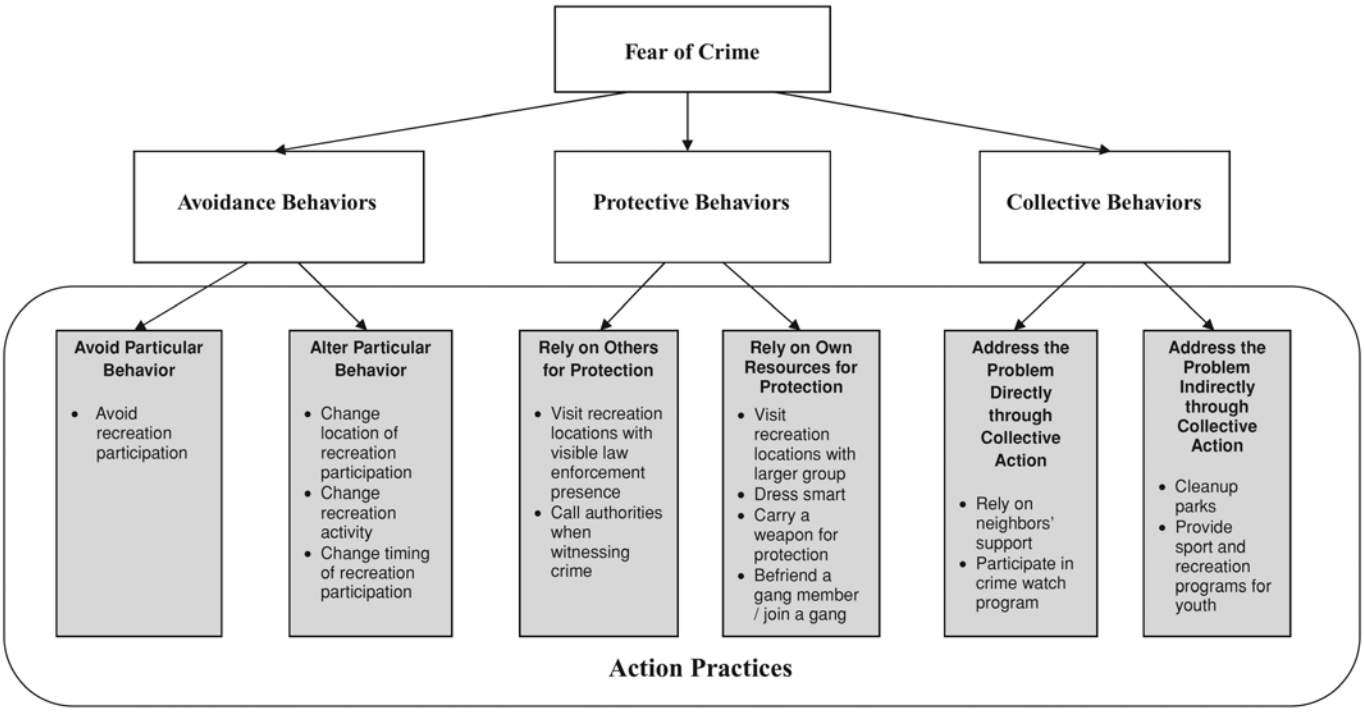
Perceptions of Crime and Its Impacts on the Use of Urban Parks by Latino Residents

Perceived safety has long been known to play an important role in people's use of urban parks, but little is known about how the everyday leisure behavior of neighborhood residents is altered by the presence of gang activity. A Northern Research Station study, in partnership with the University of Illinois at Urbana–Champaign, examined how perceptions of Latino residents in two inner-city Chicago neighborhoods affected their use of outdoor recreation environments and how they responded. Residents reported a near-constant gang

▲ "Protective" and "collective" behaviors, such as organized group picnics, are among the strategies that some residents have adopted to combat gang activities in their neighborhood parks. *Paul Gobster, Forest Service*

presence in and around the neighborhood parks studied and that drug-related activity made it particularly unsafe for residents and their children to access and use parks. Residents employed a number of strategies to cope with gang problems, including avoiding parks and neighborhood locations or altering their times of use; adopting protective behaviors, such as using parks in large groups or in the presence of police; and devising collective behaviors, such as organizing neighborhood crime watch programs, park clean-up activities, and supervised youth programs. Understanding these strategies is particularly important in inner-city and low-income communities where park space is often already at a minimum and residents have limited alternatives. This research is part of a larger study on "Recreational experiences of Latinos in urban natural environments: Preferences, benefits, and constraints" that was published in the Leisure Sciences journal and a number of other academic journals. Results of this work have also been shared with the Chicago Park District and other community stakeholder groups.

Lead: Northern Research Station



▲ Reactions to fear of crime and their relationships to recreation behavior. *Paul Gobster, Forest Service*

Multiple Studies Improve Understanding, Measurement, and Transfer of Knowledge of Recreation, Quality of Life, and Health

Pacific Southwest Research Station scientists contributed to an increased understanding of the link between recreation, quality of life, and health. Visitor constraints to physical activity in park and recreation areas, with a focus on underserved communities, were explored. Implications for visitor health were derived from this work. Pilot testing of a system for observing physical activity and recreation in natural areas led to

Outdoor Recreation

development of a draft guide and to reporting at an international meeting in Merida, Mexico. Agency research publications were synthesized and incorporated in an online resource called RECopedia, easing access to research findings, applications, and contact with key experts. RECopedia features research conducted within all the Forest Service research stations, and Research in Action stories demonstrate specific on-the-ground applications derived from the research. These efforts are aimed at furthering our understanding of the link between outdoor recreation and health and well-being and ensuring that managers and stakeholders have access to personal stories from the field demonstrating research applications. Partners in these efforts include the University of Minnesota, San Diego State University, the Forest Service Resource Use Sciences Staff, the Pacific Northwest Research Station, the Southern Research Station, and the Rocky Mountain Research Station.

Lead: Pacific Southwest Research Station

Resource Management and Use

The **Resource Management and Use** SPA provides a scientific and technological base to sustainably manage and use forest resources and forest fiber-based products. Research areas include plant science, soil science, social science, silviculture, productivity, forest and range ecology and management, forest harvesting and operations, forest and biomass products and utilization, economics, urban forestry, and climate change.

Population Dynamics of Big-leaf Mahogany in the Brazilian Amazon

Natural plant populations expand and contract in response to ever-changing physical and biological factors such as climate, topography and soils, disturbances that open growing space, competition between plants of the same and other species, and predators. Different stages of the life cycle may experience different opportunities and constraints on growth and survival, presenting ecologists who model population dynamics with densely complex puzzles to solve. For high-value tropical timber species occurring at extremely low densities on the landscape, such as mahogany, piecing the demographic puzzle together may require decades of work in hundreds or thousands of hectares of forest. The Mahogany Project seeks to understand what makes big-leaf mahogany "tick" in southeast Amazonia by monitoring vital rates for all stages of its life cycle, from seeds to senescent adults, across temporal and spatial scales relevant to each life phase. After 15 years (1995–2009) of annual censuses of more than 600 trees and many thousands of seedlings

▲ Demographic models can predict combinations of environmental conditions that lead to big mahogany trees such as this one in Brazil. *Forest Service*

▲ A flush of new growth on an ultra-fast-growing mahogany sapling. *Forest Service*

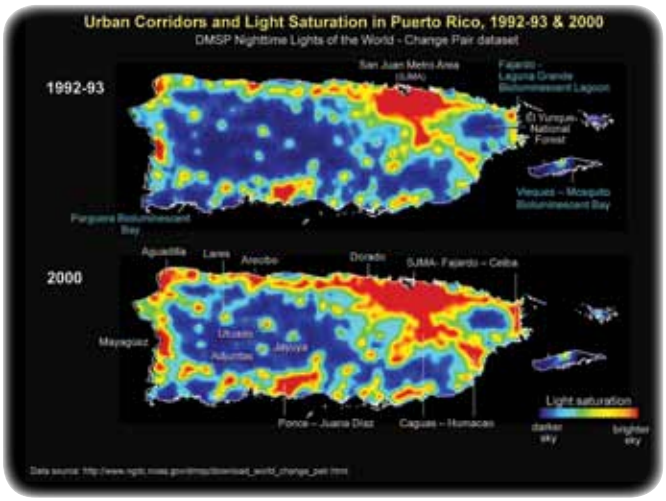
and saplings scattered across nearly 5,000 hectares of forest, the International Institute of Tropical Forestry has developed a demographic model that can be used to simulate both short- and long-term population responses to forest management practices such as minimum diameter felling limits, commercial tree retention rates, and vine cutting. Long-term growth and mortality rates of mahogany at five sites in the Brazilian Amazon indicate that a few ultra-fast-growing individuals contribute disproportionately to observed population structures. Identifying those individuals and the life-long conditions they experience may hold the key to sustained management and conservation of surviving natural populations of the world's most valuable tropical timber species.

Lead: International Institute of Tropical Forestry

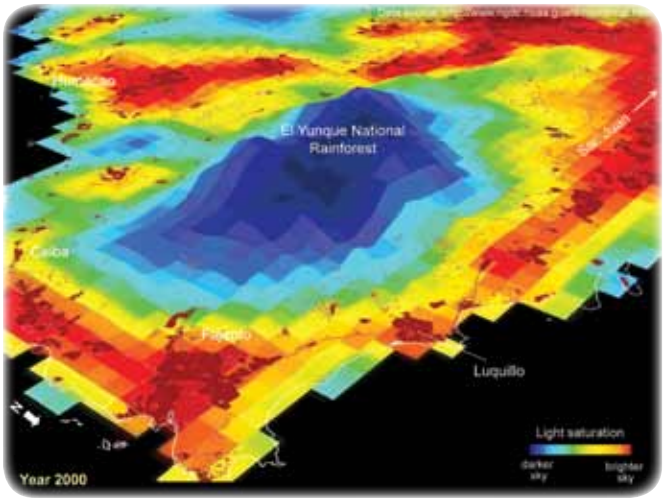
Preserving the Nighttime Environment for Future Generations in Puerto Rico

Preserving dark skies and the nighttime environment has recently become a focus of researchers studying the impacts of light pollution in Puerto Rico. In Puerto Rico, which spends an estimated $3,700 million annually on electricity for its 4 million residents, artificial illumination is the main cause of light pollution. Light pollution not only makes it more difficult to see the stars, but it also adversely impacts sensitive nocturnal species and increases energy costs and carbon emissions. Expansion of the San Juan Metro Area and other urban corridors is encroaching on upland and protected areas, causing a marked decrease in night sky quality. Currently, scientists from the International Institute of Tropical Forestry are helping to monitor artificial light pollution in Puerto Rico by customizing nighttime remote sensing imagery and map products for local use and directly monitoring nighttime lightscape conditions in the field for research, policy, and mitigation. On the periphery of El Yunque National Forest, the only tropical rainforest in the National Forest System, light pollution is obvious at uphill locations. Numerous community outreach presentations have educated children and adults about ecological and astronomical impacts of light pollution in Puerto Rico, especially in the vicinity of El Yunque National Forest. Light pollution also greatly diminishes visibility of the island's three bioluminescent bays (where high concentrations of bioluminescent microbes make the ocean glow). Since 2006, the Forest Service has worked with the Conservation Trust of Puerto Rico (CTPR) Light Pollution Task Force to implement a light pollution management strategic plan for the Bioluminescent Lagoon Demonstration Project at Las Cabezas de San Juan Nature Reserve in Fajardo, Puerto Rico. The task force and management plan aim to protect local economic revenues derived from tourists visiting these globally unique locations.

Lead: International Institute of Tropical Forestry



▲ Extent of light pollution in the islands of Puerto Rico, Vieques, and Culebra, 1992–1993 to 2000. Global data source accessible from the National Oceanic and Atmospheric Administration National Geophysical Data Center, Earth Observation Group, Defense Meteorological Satellite Program. *Forest Service*



▲ Three-dimensional perspective of the light pollution footprint in the vicinity of El Yunque National Forest. Data source: http://www.ngdc.noaa.gov/dmsp/dmsp.html. *Forest Service*

Resource Management and Use

Estate Planning for Forest Landowners

The Southern Research Station recently released an updated version of the tax planning guide, "Estate Planning for Forest Landowners: What Will Become of Your Timberland?" This publication is one of the most widely used tax guides for family forest owners and the legal, accounting, financial, insurance, and forestry professionals who serve them. The book provides guidelines and examples for effective use of planning tools for both basic and more complex forest estates. The guide also discusses insurance, trusts, and ownership of forest land and how these considerations relate to estate planning by a business entity such as a family limited partnership or limited liability company. The closing chapters summarize State estate, inheritance, and gift taxes, and illustrate the benefits of planning—or the cost of not planning—a forest estate. The guide is available in both paper and electronic form.

Lead: Southern Research Station

▲ Florida forest landowner George Owens. *Mediassociates, courtesy of Auburn University*

American Chestnut Restoration Research

The Southern Research Station and partners took a major step toward restoring the American chestnut to eastern forests. Forest Service partners include the Southern Region of the National Forest System and regional Forest Health Protection Staff. Additional partners include the University of Tennessee, the American Chestnut Foundation, and the Tennessee Division of Forestry. Hundreds of blight-resistant American chestnut trees planted last winter in three national forests in North Carolina, Tennessee, and Virginia are thriving. The station is monitoring the growth of the American chestnuts. In 2010, partners will test-plant 500 more blight-resistant chestnuts in the three national forests.

Lead: Southern Research Station

▲ Research forester Stacy Clark leads Southern Research Station efforts to determine the best way to plant the blight-resistant American chestnut seedlings developed by The American Chestnut Foundation. *Rodney Kindlund, Forest Service, (retired)*

Early Warning System Detects Seasonal Vegetation Changes

The Southern Research Station's Eastern Forest Environmental Threat Assessment Center is partnering with the National Aeronautics and Space Administration's Stennis Space Center to produce a series of seamless datasets on seasonal changes in vegetation. The early warning system is an ongoing monitoring project that detects forest threats across the continental United States using remote sensing and geographic information system technology. The data will help monitor changes to the growing season caused by climate change. The data have also proved to be very effective for hurricane assessment along the Gulf Coast and for identifying forests affected by gypsy moths.

Lead: Southern Research Station

Improving Workplace Safety in Forest Operations

With high fatality and injury rates, forest operations jobs are among the most dangerous in the United States. Accidentally thrown objects (such as machine parts, saw teeth, pieces of wood, or rock debris) are a major cause of concern for machine operators in the forest. Working with the U.S. Forest Equipment Standards Committee in the Society of Automotive Engineers and the International Organization for Standardization, Southern Research Station researchers examined the effects of material, temperature, and design variations on the risk of window failure in forest machines. Research results were translated into a new standard for testing and classifying window materials used to protect operators. This research will enhance forest equipment design around the world and improve safety in forest operations.

Lead: Southern Research Station

▲ Southern Research Station research on forest operations safety has resulted in new standards for protecting operators. *Georgia Forestry Commission*

New Management Technique Offers Promise for Longleaf Pine Forests and Beyond

Southern Research Station researchers and partners developed a new technique for managing longleaf pine forests called the Proportional-B (Pro-B) Method. Results show forest personnel can easily learn and apply Pro-B and achieve desired outcomes in the forest. This new method makes uneven-aged management more cost effective and more accessible. Station scientists believe Pro-B could revolutionize the way foresters manage forests in the future. By developing new uneven-aged management approaches, scientists are increasing the number of options available to forest managers involved in restoring and sustaining longleaf pine ecosystems.

▲ Southern Research Station researchers developed a new, more accessible method for managing longleaf pine forests. *Chris Evans, courtesy of Bugwood* (http://*www.bugwood.org*)

Lead: Southern Research Station

Regional Oak Regeneration Study

Widespread oak decline and regeneration failure threaten the sustainability of oak forests that play important ecological and economic roles in North Carolina and elsewhere in the South. Southern Research Station scientists are partnering with the North Carolina Wildlife Resources Commission and the Stevenson Land Company to initiate a regional study that focuses on the ecosystem response (regeneration of oak and other hardwood species, and plant diversity) to three recommended, but not widely tested, treatments. In addition, station researchers are partnering with professors and students at Alabama A&M University and North Carolina State University to analyze wildlife response. Researchers will use the results to develop guidelines for sustainable oak ecosystem management within southern upland hardwood forests and help ensure that these forests continue to provide valuable services.

Lead: Southern Research Station

▲ Oak regeneration plot on the Bent Creek Experimental Forest near Asheville, NC. *Rodney Kindlund, Forest Service, retired*

Resource Management and Use

Natural Fumigants Protect Wood Against Termites

Forest Products Laboratory researchers discovered that essential oils from some common plants such as dill, rosemary, and lemongrass can be used as fumigants to kill termites. Subterranean termite infestations occur in every State in the contiguous United States and are responsible for damage to wooden structures and products in excess of $2 billion annually. Environmental concerns have increased the demand for natural, environmentally friendly pesticides. Essential oils have relatively low toxicity, and some are exempt from regulation by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), making them an ideal natural pesticide for wood products in storage or in-service. Historically, essential oils have been used to control insect pests in agricultural and food storage applications, but little research had been directed toward their use to protect wood products.

Lead: Forest Products Laboratory

▲ Fumigating with essential oils from plants such as dill kills termites. *Howard F. Schwartz, Colorado State University* (http://*www.bugwood.org*)

Environmental Emissions Associated with U.S. Production of Lumber and Wood Panel Products

Life-cycle research on wood products plays a vital role in developing strategies for mitigating climate change. The main driving force behind climate change has been the release of greenhouse gases such as carbon dioxide (CO_2) into the atmosphere. During manufacturing of renewable materials such as wood products, woody biomass is burned for energy, thus helping offset the burning of fossil fuels. In addition, wood products are made from trees that reabsorb CO_2 emitted during manufacturing, thus closing the carbon cycle. In this project, Forest Products Laboratory scientists evaluated the extent of offsetting demand for fossil fuels by burning woody biomass for energy. The primary method to determine the amount and type of CO_2 released into the atmosphere is life-cycle assessment (LCA). Life-cycle inventory (LCI), a major component of LCA, tracks all material and energy inputs and outputs flowing into and out of a system boundary. For a "cradle-to-gate" LCI, the product is tracked from the forest (a tree) to the final product leaving the gate of a manufacturing facility. This LCI project examined a number of wood products made in the United States such as softwood lumber, hardwood lumber, and solid hardwood flooring. Results showed that burning woody biomass for energy during manufacturing for all these wood products greatly reduces environmental burdens by offsetting demand for fossil fuels. This project was part of a larger initiative conducted by the Consortium for Research on Renewable Industrial Materials (CORRIM, http://www.corrim.org), which includes 15 research institutions and focuses on the effects of producing and using renewable materials.

Lead: Forest Products Laboratory

Innovative Method to Determine Moisture Gradient of Wood Products

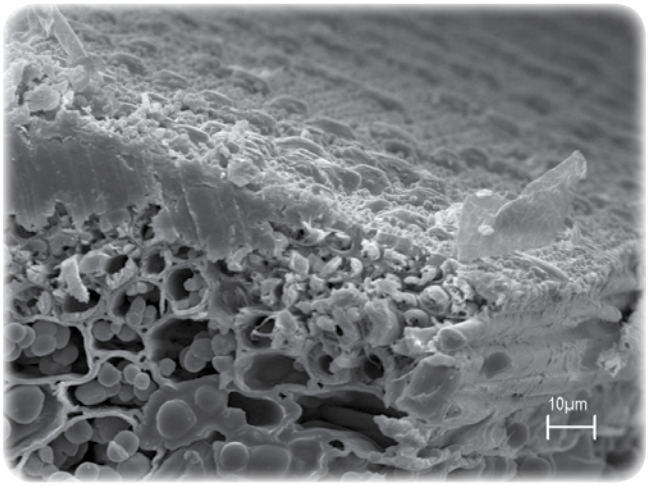
Changes in moisture content of wood-based composite materials can lead to linear expansion and, more specifically, hygroexpansion. This can cause severe internal stresses that result in deformities and defects such as warping, surface checks, and honeycomb during the wood drying process. A nondestructive method of measuring moisture content across a dimension of hygroexpansive composite material using radiation and volumetric shrinkage correction has been invented to create a profile of moisture content changes over time. The invention uses radiation to determine the depth and density of the composite material, which indicates the initial amount of moisture in the wood, and then uses volumetric shrinkage to provide a correlation of the density with a moisture content value. These measurements make up the moisture content profile of the internal movement of moisture in hygroexpansive composite material. This

profile can help researchers and manufacturers understand, control, and design a wood drying process that will reduce the occurrence of material deformities and defects. This innovation improves on previous methods for tracking changes in moisture content. Not only does it allow for continuous measurement, it also eliminates moisture loss due to testing procedures throughout the entire process. This potential on-line monitoring of moisture change in wood will help dry-kiln operators obtain optimal drying schedules and potentially improve productivity, efficiency, and energy consumption.

Lead: Forest Products Laboratory

Rice Straw: Don't Burn It, Build With It

Rice is the primary food for over 40 percent of the world's population, with about 596 million tons of rice and 570 million tons of rice straw produced annually worldwide. At present, most of these residues are burnt on site after harvest. The field burning of rice straw and other agriculture residues results in serious environmental issues and wastes precious resources. Faced with worldwide shortages of forest resources, environmental pollution, and waste of biological resources resulting from field burning of rice straw and other agriculture residues, interest in using rice straw and other agriculture residues to produce building materials, including composite panels, has grown. This research aims to evaluate mechanical and physical properties of particleboard made from six different categories of hammer-milled rice straw and two types of resin. The performance of straw particleboard is highly dependent on the straw particle size. Static bending and internal bonding strengths of boards made with polymeric diphenylmethane diisocyanate (pMDI) resin initially increase and then decrease with decreasing particle size. Thickness swelling, water absorption, and linear expansion of particleboards decrease with increasing particle size. Compared with pMDI-resin-bonded panels, rice straw particleboard bonded using urea-formaldehyde resin exhibits much poorer performance. Optimized panel properties exceeded the M-2 specification of American National Standard for Wood Particleboard. Scientists at the Forest Products Laboratory and the Egyptian National Research Center collaborated on this research.



▲ Surface characteristics of rice straw. *Zhiyong Cai, Forest Service*

Lead: Forest Products Laboratory

Sterilize Firewood With Heat To Kill Emerald Ash Borer

The emerald ash borer (EAB) is a nonnative bark- and wood-infesting insect that poses an enormous threat to North American urban and rural forests. Because of the potential risk associated with moving ash firewood infested with EAB, interstate movement of all hardwood firewood is restricted under Federal quarantine. Communities and firewood producers are faced with challenges in implementing heat sterilization and safely treating their firewood for interstate commerce. Working with the wood engineering group at the University of Minnesota–Duluth, Forest Products Laboratory researchers have led a joint research effort with USDA Animal and Plant Health Inspection Service (APHIS) and State regulatory staff to evaluate various heat-treatment options and heating times for ash firewood and to help the firewood industry successfully implement the heat treatment process as required by new USDA phytosanitary regulations. Completion of laboratory experiments and field trials has resulted in practical and effective heat treating schedules for thermally eradicating EAB and other nonnative invasive species in firewood. The information benefits firewood producers in planning and executing effective heat treatment of hardwood firewood and helps USDA APHIS and State governments to develop feasible certification and auditing protocols for better enforcing the Federal regulations. The team conducted heat-treatment demonstrations at four firewood-treating facilities in Wisconsin, Illinois, and Indiana. Researchers conducted

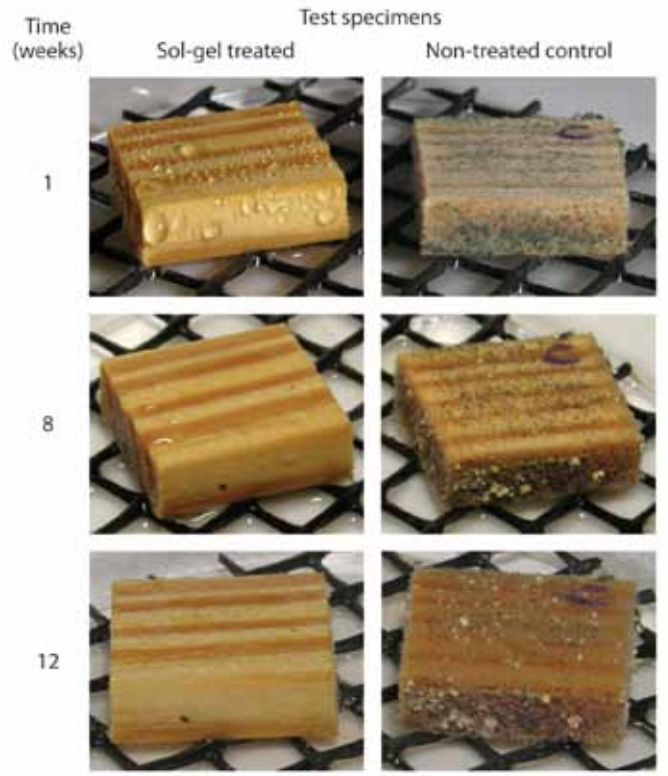
an on-site training workshop and a Web-based training seminar that were well received by firewood producers and APHIS and State field regulatory staff.

Lead: Forest Products Laboratory

▲ A firewood heat-treatment facility to combat emerald ash borer, Prairie du Sac, WI. *Xiping Wang, Forest Service*

Sol-Gel Technology Improves Wood Durability

Various approaches have been developed over the centuries to improve the durability of wood for use under different environmental conditions. For example, to protect wood from damage caused by wood-destroying fungi or wood-staining mold, wood has been impregnated with toxic chemicals that prevent wood decay or mold colonization. Although this approach has been successful in improving the durability of wood against fungal or mold growth, its environmental sustainability has come under increased scrutiny. Reports have emerged indicating that production, treatment, and waste management of wood-protection chemicals has had a negative impact on the environment. Consequently, intensive research is required to develop new environmentally sustainable technologies for improving the durability of wood used in residential construction. With support from industry partners, Forest Products Laboratory researchers are developing new sol-gel technologies to enhance performance properties of wood or wood fiber. Sol-gel technologies are wet-chemical techniques that are widely used in the fields of materials science and ceramic engineering. Specifically, in situ sol-gel deposition of hybrid inorganic–organic thin films on wood substrates greatly improves their resistance to mold growth. In addition to using nontoxic ingredients, sol-gel modification of wood is energy efficient.



▲ Comparison of sol-gel-treated (left) and untreated wood specimens and mixed mold growth results over 12 weeks. *Steve Schmieding, Forest Service*

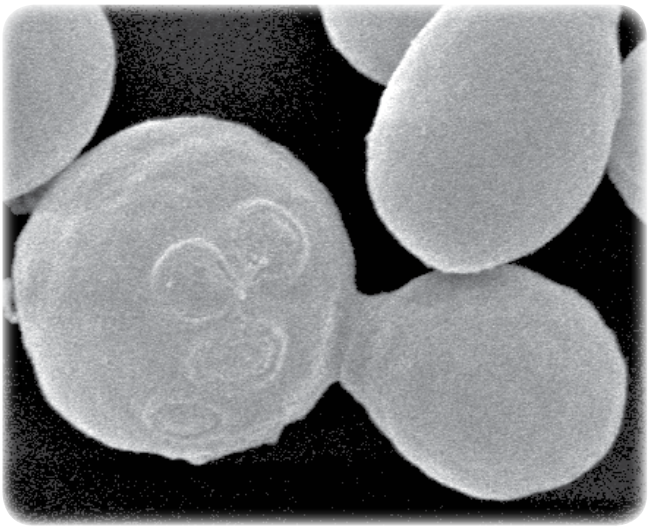
Lead: Forest Products Laboratory

Fast-Forward Genetics for Renewable Fuels

Genetic studies traditionally proceed in a stepwise fashion, with each mutant or transformant gene being characterized as it is developed. Improved strains are obtained and used often without knowledge of the changes involved. Although this approach is useful commercially, recreating these improvements in other strains and understanding their basis are difficult. In recent years, however, high-throughput genetic sequencing has enabled exact nucleotide characterization of entire genomes. Researchers at the Forest Products Laboratory used mutagenesis, strain selection, and genetic manipulation over a period of 7 years to develop improved strains of yeasts that will produce renewable fuel (ethanol) from

wood residues. In a collaboration between the Forest Products Laboratory and the Department of Energy Joint Genome Institute, researchers sequenced the genome of the parental yeast, *Pichia stipitis* CBS 6054, in 2006. They then resequenced and characterized four sequentially derived mutants of the parent. Surprisingly, they found only 14 separate nucleotide changes despite several rounds of mutagenesis and selection. This work—the use of direct sequencing to characterize improved mutant strains from a eukaryotic organism—was the first of its kind. These findings will enable more rapid development of yeasts for the bioconversion of wood residues to fuels and chemicals.

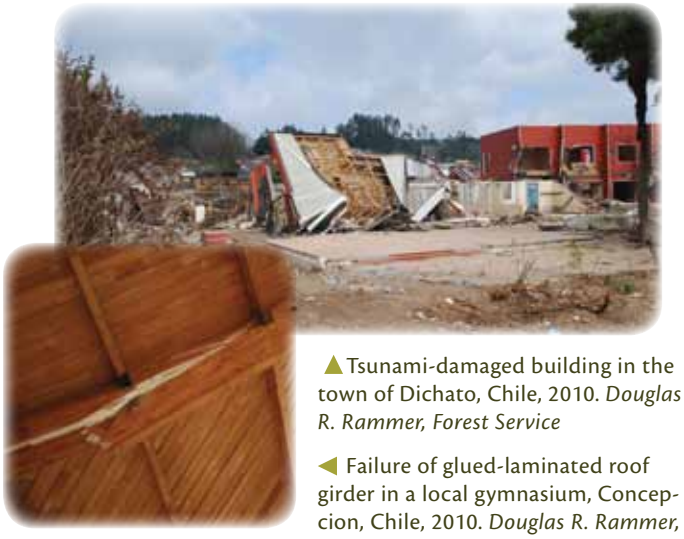
Lead: Forest Products Laboratory



▲ The unconventional yeast, *Pichia stipitis*, will ferment both cellulosic and hemicellulosic sugars to ethanol. *Thomas Kuster, Forest Service*

Performance of High-Rise Wood Structures in Earthquake Zones

On February 27, 2010, a magnitude 8.8 earthquake occurred off the west coast of Chile, more than 95 kilometers north of Concepción and about 250 miles southwest of the capital, Santiago. More than 340 people were killed, and tsunami warnings were generated as far away as Russia. A team of technical experts from the American Society of Civil Engineering–Structural Engineering Institute, including Forest Products Laboratory scientists, traveled to Chile to document the performance of structures and assess whether changes to current U.S. building codes and standards might be warranted. U.S.



▲ Tsunami-damaged building in the town of Dichato, Chile, 2010. *Douglas R. Rammer, Forest Service*

◀ Failure of glued-laminated roof girder in a local gymnasium, Concepcion, Chile, 2010. *Douglas R. Rammer, Forest Service*

Geological Survey scientists believe a similar type of earthquake could occur in the United States, particularly in the Pacific Northwest region between northern California and Seattle, WA. The 20-member team was in Santiago and Concepción from April 5–12, 2010. Forest Products Laboratory scientists were actively involved in field assessments of low-rise structures, particularly wood structures, looking for seismic and tsunami damage in Concepción, San Pedro de la Paz, Talcahuano, and Dichato. The scientists made presentations to Chilean wood industry representatives and government officials regarding the Forest Products Laboratory's international research effort on the structural performance of multistory wood-frame structures subjected to simulated earthquakes. This research is aimed at reducing the seismic risk of high-rise wood structures and is a cooperative effort with partners from Colorado State University, Simpson Strong Tie, Texas A&M University, SUNY University at Buffalo, Rensselaer Polytechnic Institute, University of Delaware, and FP Innovations.

Lead: Forest Products Laboratory

Determining the Cost of Biomass Removal

Removing accumulations of woody biomass from the forest reduces fire fuel and provides wood for power generation and ethanol production. Is the value of the biomass high enough to cover the cost of removing it? Forest managers can now use a computer spreadsheet tool to find out. The Western Biomass Tool estimates the costs of harvesting, chipping, and transporting biomass.

Resource Management and Use

The Western Biomass Tool can also be used to calculate the cost of removal purely as a fuel-management measure. Both applications are valuable to managers who need to understand the economic viability of their proposed management activities. Funded through the Forest Service National Fire Plan, development of the tool was a collaborative effort by Forest Service researchers and the University of Idaho.

Lead: Rocky Mountain Research Station

▲ Skidder and delimber operating on a fuel management research project on the Priest River Experimental Forest. *W. Elliot, Forest Service*

Analysis of Douglas-fir Climate Change Adaptation Potential

A collaborative effort led by the Rocky Mountain Research Station has resulted in a report outlining the impact of changing climate on forest distribution, particularly that of Douglas-fir. Douglas-fir is the top-valued forest product tree in the West, and understanding its ecological and evolutionary potential is necessary to understand its future commercial value. The research was in response to the need to understand how climate change will affect Douglas-fir's distribution, ability to migrate, and ability to adapt and survive where it is. The study is unprecedented in size, with thousands of samples collected from throughout the Intermountain West, from Canada to Mexico. The study results are critical to land managers who must develop adaptation strategies and proactive management decisions and to the public, which values forests for water resources, wildlife, and timber production. This research was made possible by successful collaboration among scientists from the Pacific Southwest Research Station, Pacific Northwest Research Station, regional Forest Inventory and Analysis, Oregon State University, and University of Washington Climate Impacts Group.

Lead: Rocky Mountain Research Station

Land Use Policies Affect Levels of Carbon Sequestration

Researchers used the Forest and Agriculture Sector Optimization Model–Greenhouse Gases model to analyze alternative policy scenarios and compare their potential influence on land use and, thereby, how they affect carbon sequestration and other environmental and economic benefits. The "business as usual" scenario suggests that the amount of forest land converted to more developed uses will be substantial, causing a significant net release of greenhouse gases currently stored in those forests. Scenarios involving carbon-related payments to U.S. private forest landowners led to increased carbon sequestration. Modeling results suggest that carbon-related payments to forestry or agriculture landowners can substantially affect future land use patterns, levels of terrestrial carbon sequestration, forest resource conditions, agricultural production trends, and bioenergy production. The U.S. Environmental Protection Agency, USDA's Global Change Program Office, and congressional staff have used the models and findings from this work to analyze legislative proposals that address climate change and new policies that affect land use, such as the 2007 Energy Independence and Security Act and the Conservation Reserve Program provisions of the 2008 farm bill. The research is also being used to inform decisionmaking under the Forest Service's Forest Legacy Program, and it has attracted international recognition. Australia consulted with the scientists for advice on addressing climate change, and spinoff modeling systems have been developed in Europe and elsewhere. Research partners include Oregon State University, Duke University, and Texas A&M University.

Lead: Pacific Northwest Research Station

▲ Land use competition among forestry, agriculture, and development influences the amount of terrestrial carbon storage. *Ralph Alig, Forest Service*

Harvest Pattern Influences Survival of Forest-Dependent Species

Researchers established the Demonstration of Ecosystem Management Options (DEMO) study in 1994 to evaluate the benefits of leaving some live trees standing as part of harvest treatments. The percentage of trees retained ranged from 15 to 100, and the retention pattern also differed among study sites in mature Douglas-fir forests. Short-term results suggest that both dispersed and aggregated retention are needed to retain sensitive plants and animals, ameliorate harsh microclimatic conditions, and gain public acceptance of retention harvests. Although the retention level had a greater influence on most ecological responses than did its pattern, retaining trees in aggregates of a hectare provided several benefits over dispersed retention. Aggregates greatly reduced damage to and mortality of residual trees (particularly at lower retention levels) and provided short-term refugia for forest species sensitive to disturbance or environmental stress. Based on these findings, a combination of aggregates larger than a hectare and dispersed retention at levels considerably greater than the current minimum standard of 15 percent appears a general strategy for ensuring the short-term persistence (and, presumably, the long-term recovery) of most forest-dependent species. It also appears to be an effective treatment for gaining public acceptance of green-tree retention that sustains the ecological and commodity values of managed forests. These studies have garnered international interest—both in the findings and in the safety and operational aspects of green-tree-retention harvests. Land managers in the Pacific Northwest, British Columbia, and Tasmania have applied DEMO findings to forest management. Research partners include Oregon State University, University of Oregon, University of Washington, Umpqua and Gifford Pinchot National Forests, and Washington State Department of Natural Resources.

Lead: Pacific Northwest Research Station

▲ Foresters examine the Blue Ridge study site in Washington's Capitol State Forest as part of the Demonstration of Ecosystem Management Options Study. *Tom Iraci, Forest Service (retired)*

▲ *Trillium grandiflorum* flowering is an indicator of low deer browsing pressure at the Kinzua Quality Deer Cooperative. *Stephen B. Horsley, Forest Service (retired)*

Landscape-Level Deer Herd Reductions Alter Forest Understory

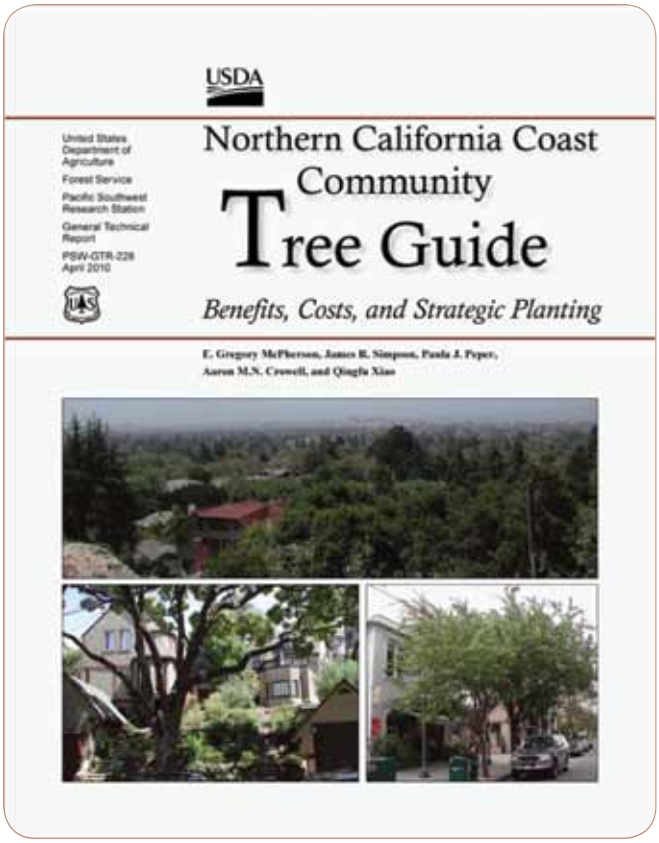
White-tailed deer overbrowsing has altered forest understory plant species diversity throughout eastern North America. Since 2001, a Northern Research Station study has tracked the response of herbaceous plant communities to deer herd reductions throughout the 70,000-acre Kinzua Quality Deer Cooperative (KQDC) in northwestern Pennsylvania. The study—in partnership with Allegheny National Forest, Bradford Watershed, Forestry Investment Associates, Collins Pine, RAM Forest Products, and Sand County Foundation—found rapid, dramatic increases in overall forb and shrub cover of deer-palatable understory plants, such as trilliums and Canada mayflower, but no changes in plant species diversity. Thus, controlling deer alone may not promote diversity in overbrowsed, species-poor forests without additional restoration strategies. These results are being incorporated into a vegetation monitoring proposal by the Pennsylvania Bureau of Forestry for use in its million hectares of State forests.

Lead: Northern Research Station

Resource Management and Use

Community Tree Guides Help Managers Show That Trees Pay Us Back

In 1998, Pacific Southwest Research Station scientists began extensive measurements of 900 city trees in Modesto, CA, to calculate their benefits and costs. The following year, publication of "Tree Guidelines for San Joaquin Valley Communities" gave managers a tool to calculate the value of new tree plantings in terms of future energy savings, carbon sequestration, air pollutant uptake, stormwater runoff reduction, and property value increase. The 65-page, peer-reviewed publication contains information on typical tree planting and stewardship costs and guidelines for selecting, siting, and planting trees to maximize energy savings and other benefits. Subsequent guides have included examples of how benefit–cost information can be adjusted for local conditions for a particular planting project. In 2010, the 16th and final community tree guide was published for central Florida based on research conducted in Orlando. Any user can now compare future net benefits from alternative tree planting scenarios in any area of the United States. In Minnesota, a series of workshops helped communities use a spreadsheet template with data from the "Midwest Community Tree Guide" to calculate net benefits for their tree planting projects. In California, United Voices for Better Communities used data from "Tree Guidelines for Inland Empire Communities" to estimate future air pollutant uptake benefits for a planting project funded by the South Coast Air Quality Management District. Sixteen companion brochures published by the Pacific Southwest Research Station distill information from the community tree guides into common language for decisionmakers and residents. The community tree guides are providing credible information on the net benefits of well-managed urban forests that is timely as cities try to protect and restore environmental quality while enhancing economic opportunity. Research that underpins the tree guides has been incorporated into tree benefit calculators that are used in thousands of communities across the United States. The series was produced with funding provided primarily by the Forest Service, State and Private Forestry, Urban and Community Forestry Program. Several State forestry agencies and community tree councils, Davey Tree Expert Co., Local Government Commission, and each of the municipalities where research was conducted provided additional funding and support.



Lead: Pacific Southwest Research Station

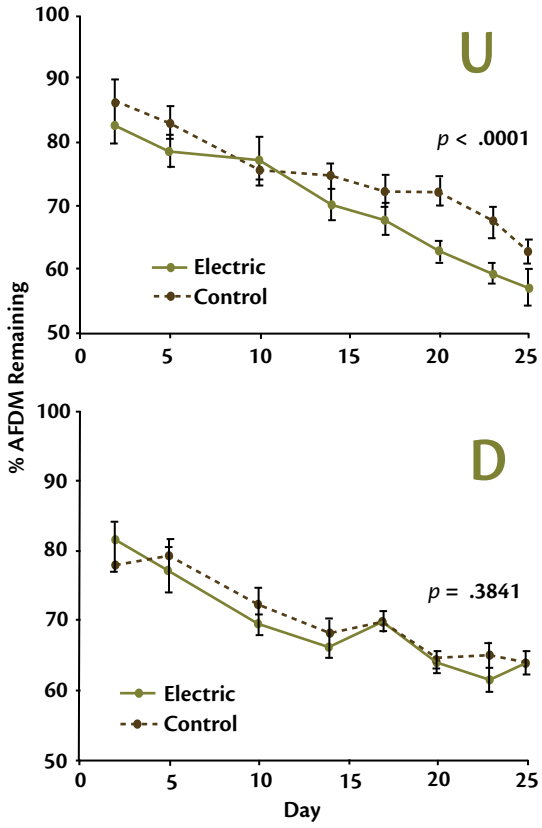
Water, Air, and Soil

The **Water, Air, and Soil** SPA informs the sustainable management of these essential resources through information on how to provide clean air and drinking water, protect lives and property from wildfire and smoke, and improve the ability to adapt to climate variability and change. It encompasses studies on ecosystem services with integration between water, air, and soil research. The SPA notes the effects of climate variability and change on water budgets.

Dams Slow Decomposition of Leaf Detritus by Eliminating Shrimp

Dams can cause dramatic changes to streams and rivers. In Puerto Rico, most native freshwater shrimps and fishes migrate from estuaries to headwaters at some point in their life cycle. However, migratory species have been completely extirpated from about 27 percent of rivers due to dams. Without dams, high-elevation streams are dominated by shrimps (up to 25 per square meter) that control decomposition and other ecosystem processes. Research in partnership with the University of Georgia found that when shrimp are blocked from migrating upstream, their absence causes drastic changes to stream ecosystems. Streams above large dams show higher levels of algae biomass, nitrogen concentration, and fine benthic organic matter. Leaf litter decomposition rates were 66 percent higher in undammed streams. An in-stream exclosure experiment showed that shrimp extirpation is a significant factor in the reduced leaf breakdown rates for streams above large dams. Slower decomposition results in more detritus being washed downstream and into the ocean, where it interferes with coral reef dynamics. The shift in detrital breakdown from shrimp to microbes also results in more nitrogen release to the water, which enhances algal blooms and changes food web relationships.

Lead: International Institute of Tropical Forestry



▲ Percentage of ash-free dry mass (AFDM) remaining over time for the shrimp exclusion (electric) and shrimp access treatments in dammed (bottom, Limon Stream) and undammed (top, Cain River) streams. Shrimp exclusion resulted in higher AFDM remaining over time for the undammed stream, whereas no difference was detected between treatments in the dammed stream. *Forest Service*

▲ Cain River, Puerto Rico. Macrobrachium shrimp species are important to processing leaf detritus in Caribbean streams, but dams keep them from accessing headwaters. *Pedro J. Torres, University of Georgia*

Climate Change Impacts on Ecosystem Services: Water, Carbon, and Biodiversity

The Southern Research Station is enhancing one of its models that examines potential impacts of climate change, land use, and population changes on water supplies. Researchers are building this integrated,

▲ Eighty percent of the Nation's drinking water originates in forests. *Dave Dwinnell, Forest Service [deceased]*

water-centered modeling on previous water supply and demand research that resulted in a Water Supply Stress Index (WaSSI) model. Scientists have used the WaSSI model to examine potential impacts of climate, land use, and population changes individually or in combination. Scientists are developing the new model, known as WaSSI–Carbon and Biodiversity, or WaSSI–CB, by literature synthesis of international carbon fluxes network data and regional relationships among climate and ecosystem processes. The new model will be developed and applied in the United States and internationally in Asia and South America.

Lead: Southern Research Station

Forest Fungi Are Natural Cleanup Agents in the Environment

Forest fungi perform an essential role in recycling woody plant debris and have many potential applications in biotechnology. In 2009, a Forest Products Laboratory chemist worked for 10 months as a Senior Fulbright Awardee at the International Graduate School in Zittau, Germany. The research, conducted in collaboration with the German scientists, dealt with a recently discovered and unusual enzyme secreted by Agrocybe aegerita, otherwise known as the edible black poplar mushroom. The results showed that this enzyme, known as a peroxygenase, degraded some ethers that have emerged as serious environmental pollutants. Notably, the peroxygenase oxidized dioxane and tetrahydrofuran, both of which are widespread groundwater contaminants. This work points out the importance of forest fungi as natural cleanup agents in the environment and opens the possibility that their enzymes might be used to detoxify polluted water.

▲ The edible black poplar mushroom, *Agrocybe aegerita*. *Tom Volk, University of Wisconsin-La Crosse (http://www.tomvolkfungi.net)*

Lead: Forest Products Laboratory

▲ Bull trout in pristine central Idaho streams are a sensitive species likely to be affected by climate change. *Bart Garnett, Forest Service*

Climate Change Effects on Stream Temperature

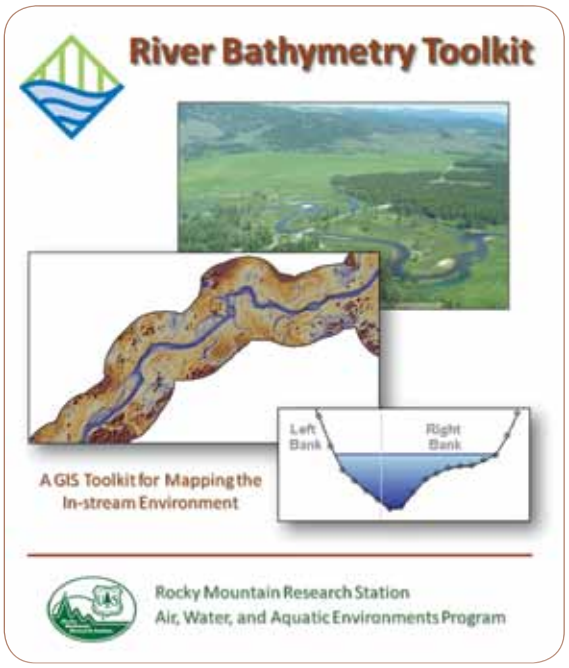
Climate change affects stream temperature, which in turn affects fish and other aquatic organisms. A new temperature model developed through collaboration between researchers at the Rocky Mountain Research Station's Aquatic Sciences Laboratory and the Australian Commonwealth Scientific and Research Organization can accurately predict stream temperatures, rates of climate warming, and habitat loss for sensitive species across large river networks. The model integrates temperature information, commonly collected by the Forest Service and other agencies, with geographic information system and remote-sensing technologies to give decisionmakers an expanded base of information to consider when making investment decisions for stream-restoration projects. The model was first developed to estimate the effects of climate change on streams draining the Boise River Basin in central Idaho and has recently been extended to provide historical and future temperature predictions for all streams on the Payette National Forest. The temperature model advances the water resources protection and enhancement goal that Agriculture Secretary Tom Vilsack and Forest Service Chief Tom Tidwell set forth in their shared vision for America's forests.

Lead: Rocky Mountain Research Station

New Toolkit Automates the Interpretation of Digital Channel Maps

Rocky Mountain Research Station scientists are developing a computer application—the River Bathymetry Toolkit (RBT)—that automatically extracts quantitative channel shape information from digital maps. This research and development has been funded by the Rocky Mountain Research Station, the National Oceanic and Atmospheric Administration, and the Bonneville Power Administration, all of which recognized the RBT as an answer to the need for a safer, faster, and simpler way to describe channel structure and habitat. The RBT can measure a channel at thousands of locations on a digital model, instead of a researcher wading into the channel at several locations to take only a few samples. The technology can also be used to assess climate change impacts because it allows scientists to map and describe critical areas, such as off-channel habitat, in the current state and under different climate change scenarios. The RBT benefits people who are concerned about threatened and endangered species because it informs watershed managers, fish biologists, and aquatic ecologists, allowing them to make better decisions. In combination with new remote sensing methods for mapping channels, this tool gives scientists a more powerful way to describe aquatic habitat and the physical characteristics of a channel.

Lead: Rocky Mountain Research Station



▲ Cover of RBT user's guide. The RBT has removed the general valley slope from a digital map of a meandering stream to highlight the local "off-channel" habitat composed of old channel paths in the floodplain that are now filled only during high flows. The RBT also calculates a variety of measures of cross-sectional geometry of channels at user-defined locations (bottom illustration). *Jim McKean, Forest Service*

New Methods Quantify Fluxes of Carbon From Terrestrial and Aquatic Ecosystems in Southeast Alaska

Mitigating increases in atmospheric carbon dioxide by increasing forest sequestration of carbon is a high priority for forest managers. Assessing management impacts on carbon in aboveground vegetation is straightforward, but accounting for fluxes from belowground storage pools is challenging. Projected changes in temperature and moisture over the next 80 years could dramatically increase the release of carbon currently stored in soil. In a rainforest, such as the Tongass National Forest, where terrestrial and aquatic systems are closely linked, increases in the amount of carbon and associated nutrients exported to coastal estuaries could have far-reaching impacts on estuarine productivity and fish habitat. Changes in freshwater fish habitat quality stemming from increased mobilization of dissolved organic matter, increased water temperature, and higher stream respiration could affect survival of salmon during egg

▲ Researchers collect soil samples from peatland (muskeg) in southeast Alaska as part of a study on carbon flux between terrestrial and aquatic systems. *Rick T. Edwards, Forest Service*

development and early juvenile stages. Scientists in southeast Alaska have established methods for quantifying fluxes of carbon from terrestrial and aquatic ecosystems across a gradient of forest structures. These methods provide a powerful approach to understanding short- and long-term carbon sequestration on the forest, which can then be applied to regional and national carbon sequestration goals. Partners in this research include Pacific Northwest Research Station, University of Alaska Southeast, and the USDA National Institute of Food and Agriculture.

Lead: Pacific Northwest Research Station

Soils in Douglas-fir Plantations in the Oregon Coast Range Have High Rates of Methane Uptake

Methane is a particularly potent greenhouse gas. Since the 1750s, the increase in atmospheric methane has contributed to about 20 percent of the enhanced greenhouse effect. Forest soils are both a source and a sink for the gas. Methane is a byproduct of chemical reactions occurring in very wet, anaerobic soil, but it is absorbed during different chemical reactions occurring in drier soils. Despite its potential to affect the Earth's climate, limited sampling has been done to determine the rates of exchange for soil uptake and production for several major ecosystems. Pacific Northwest Research Station scientists, in partnership with the U.S. Geological Survey, conducted the first study to report methane uptake rates by forest soil in the Pacific Northwest. In 2008, methane uptake was measured five times from three Douglas-fir stands in the Coast Range of Oregon. Uptake was similar across the sites and was high compared with most other coniferous forests globally. This is most likely a result of the well-drained, highly porous, volcanic soils at the sites. The overall high rates suggest that these forests offset methane emissions more than coniferous forests outside the region. This information on rates of methane uptake can be used in greenhouse gas accounting efforts.

Lead: Pacific Northwest Research Station

Climate Change Effects on Streamflow

Climate change has the potential to alter streamflow regimes, which has ecological, economic, and social implications. In the Northeastern United States, it is unclear how climate change may affect the surface water supply, which is critically important in this densely populated region. Northern Research Station and collaborators from Syracuse University and Texas Tech University have been evaluating the impact of climate change on streamflow at small gauged watersheds at the Hubbard Brook Experimental Forest in New Hampshire. These headwater streams are the source waters for larger rivers and therefore may serve as an indicator for potential climate change effects. This research evaluated long-term hydrologic data and modeled future streamflow through the end of the 21st century using several climate change scenarios. Preliminary results indicate that earlier snowmelt and diminishing snowpack are advancing the timing and reducing the magnitude of peak discharge associated with snowmelt. However, little change in overall quantity of streamflow is seen because increases in precipitation offset increases in water loss by evaporation and plant transpiration. This study is improving our understanding of the hydrological consequences of climate change and will begin to provide a foundation for sound future decisionmaking on climate change policy.

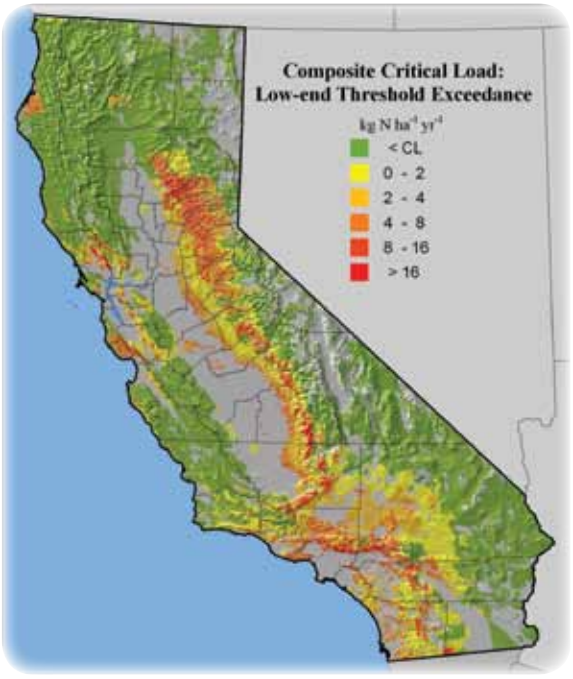
Lead: Northern Research Station

▲ Streamflow during snowmelt at Hubbard Brook Experimental Forest. *Jim Hornbeck, Forest Service*

New Maps Help Protect California From an Overload of Atmospheric Nitrogen

Many ecosystems in California are being harmed as a result of nitrogen pollution from the atmosphere. High levels of nitrogen deposition (greater than 10 kilograms of nitrogen per hectare each year) negatively affect over 50,000 square kilometers of land in the State. Primary sources of this nitrogen pollution in California are motor vehicles, agriculture, and, to a lesser degree, industry. Nitrogen emissions to the atmosphere are 3 to 10 times greater in California than in the other 10 Western States. These chronic atmospheric inputs of nitrogen pollution cause ecosystem nutrient enrichment effects that are analogous to overfertilization of crop fields. Pacific Southwest Research Station scientists developed nitrogen critical load exceedance maps to help air pollution emissions regulators, air quality specialists, and land managers protect ecosystems affected by excess nitrogen. These maps indicate where ecosystems in California are at risk from too much nitrogen deposition and where, and by how much, atmospheric nitrogen deposition needs to be reduced. The maps are already being used in California by Forest Service and National Park Service air quality specialists and in Europe under the auspices of the Convention on Long-Range Transboundary Air Pollution, a program of the United Nations Economic Commission for Europe.

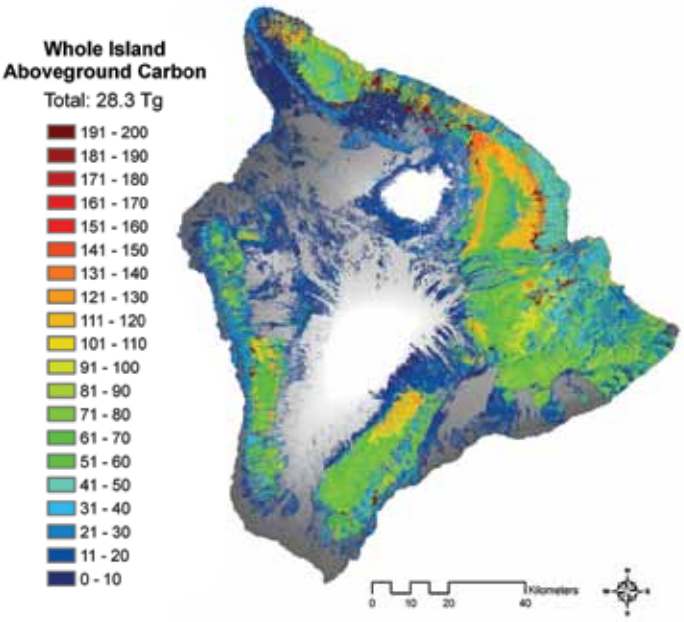
Lead: Pacific Southwest Research Station



▲ Areas of nitrogen critical load exceedances in seven vegetation types in California. *Forest Service*

Forest Carbon Mapping Approach Is Cost-Effective

Large-scale biomass mapping is essential to support the United Nations Framework Convention on Climate Change (UNFCCC) program to Reduce Emissions from Deforestation and Forest Degradation (REDD). In collaboration with scientists from the Carnegie Institute of Science (CIS), Pacific Southwest Research Station researchers have developed and tested an integrated satellite, airborne, and field-based mapping approach that supports high-resolution biomass monitoring of tropical forest regions. CIS and Pacific Southwest Research Station researchers tested this approach on the island of Hawaii at a resolution of 0.1 hectare, making it the largest high-resolution biomass mapping study of its kind. Results indicate that Hawaii Island supports an estimated 60 teragrams in aboveground biomass (30 teragrams C). Researchers presented these results and approach at the Copenhagen-15 meetings in December 2009, where they were received with great interest. These results clearly demonstrate that a combination of free satellite monitoring technology coupled with an affordable



▲ Hawaii's forest carbon mapped at 30-meter resolution using the CLASlite–LiDAR approach. *Forest Service*

Water, Air, and Soil

level of aircraft-based LiDAR (light detection and ranging) mapping can provide spatially resolved regional biomass estimates that will improve the monitoring of carbon stocks, losses and recovery in forests over time. These tools are now available and can be implemented in any region of the world, making rapid forest carbon mapping a reality.

Lead: Pacific Southwest Research Station

Wildlife and Fish

The **Wildlife and Fish** SPA relies upon interdisciplinary research to inform policy initiatives affecting wildlife and fish habitat on private and public lands and the recovery of threatened or endangered species. Scientists in this program area investigate the complex interactions among species, ecosystem dynamics and processes, land use and management, and emerging broad-scale threats, including global climate change, loss of open space, invasive species, and disease.

Linking Temperate Breeding Grounds Conservation With Tropical Wintering Grounds Conservation in the Endangered Kirtland's Warbler

Kirtland's Warbler is one of North America's most endangered migrant songbirds. Almost the entire population breeds in the northern lower peninsula of Michigan and winters in the Bahamas Archipelago, where little was previously known of its conservation needs. In a recent publication, International Institute of Tropical Forestry scientists and cooperators characterized the warbler's winter habitat using a combination of habitat measures in the field and remote sensing imagery. They found that the warbler's winter habitat consists primarily of low scrub species in early stages of succession (6 to 28 years after human activity disturbed the area) and containing fruit that the warbler readily consumes. Warblers abandon sites as fruit production ceases, shifting to new sites where fruit is more abundant. These findings indicate that simply protecting parcels of land where succession is allowed to run its course, without disturbance, will at some point result in insufficient winter habitat for the warbler. Forest Service scientists and cooperators are working with goat farmers, utility companies, and other landowners to encourage recurring disturbances that benefit the warbler. The birds are often abundant on goat farms (where goats consume plants that compete with the warbler's fruit plants) and utility corridors (where vegetation is periodically cut or plowed to reduce growth and contact with utility lines). Some of the bird's prime fruit plants respond well to periodic cutting, mowing, or even bulldozing and can re-sprout and fruit shortly thereafter, suggesting they may thrive not only in utility corridors but also in boundary lines and fire breaks. Harnessing these preexisting disturbances to better favor the warbler's fruit plants should make it possible to implement cost-effective management for the warbler on private lands throughout the archipelago.

▲ Kirtland's Warblers photographed by project participants on the warbler's wintering grounds on Eleuthera, The Bahamas. *Dave Currie, Puerto Rican Conservation Foundation*

▲ Ingeria Miller, a project student intern, with a captured Kirtland's Warbler on Eleuthera, The Bahamas. *Dave Currie, Puerto Rican Conservation Foundation*

Lead: International Institute of Tropical Forestry

▲ Natural producers of Kirtland's Warbler winter habitat were likely hurricanes and fire; now human disturbances, such as bulldozing, goat grazing, mowing, or brush-hogging, create winter habitat for the warbler. The range of successional stages following disturbances are shown in the lower photos. *Joseph M. Wunderle, Jr., Forest Service*

Riparian Zones

In a recent study on the Nantahala National Forest in western North Carolina, Southern Research Station scientists investigated the importance of riparian zones to bats and salamanders and tested the effects of riparian zone width on these important taxa. These wildlife groups were chosen for study because of their prominent roles in forested ecosystems of the Southern Appalachians, their associations with riparian areas, and grave concerns about their conservation status. Forest managers can use these findings to maintain habitat sufficient to conserve bat and salamander populations.

Lead: Southern Research Station

▲ Indiana bat (*Myotis sodalis*). *Jerry A. Payne, USDA Agricultural Research Service, courtesy of Bugwood (http://www.bugwood.org)*

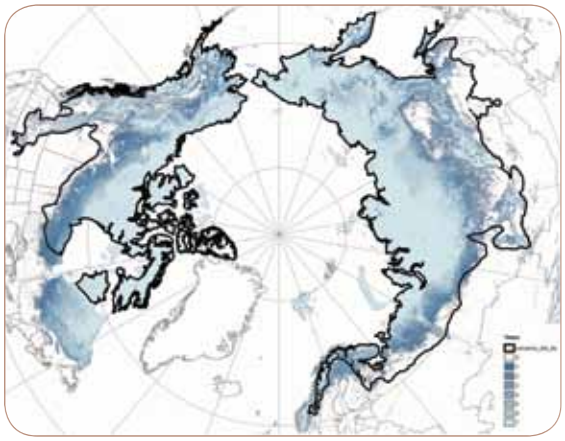
Wolverine Futures in a Changing Climate

Rocky Mountain Research Station researchers have demonstrated that wolverines are dependent on persistent spring snow for denning, a critical factor for determining the future extent and survival of wolverine populations. To build on this understanding, National Forest System and U.S. Fish and Wildlife Service partners provided funding for the Rocky Mountain Research Station to work with the University of Washington Climate Impacts Group to predict where suitable snow might exist for this species in the future. Researchers are using these research results for wolverine reintroduction. The U.S. Fish and Wildlife Service is also using the results as it examines the wolverine as a candidate for listing as a threatened or endangered species. Colorado and California, where wolverines were eliminated completely in the last century, are now seen as suitable sites for reintroductions. Getting reintroduction efforts right the first time is important—there are few wolverine populations to draw from and the reintroduction process is very expensive. The Rocky Mountain Research Station has also found ways to use models derived from current genetic patterns and apply them to future landscapes to inform land management decisions on current and likely future corridor locations. It has partnered with multiple State and private agen-

cies to provide maps identifying corridor locations that optimize wolverine population connectivity. Although current efforts are focused on wolverines, these new tools can be applied to a variety of organisms to inform potential management decisions in a changing climate.

Lead: Rocky Mountain Research Station

▲ A Rocky Mountain Research Station technician searches for wolverines in Glacier Park, Montana. *Jeff Copeland, Forest Service*



▲ Wolverine range, May snow cover. Wolverines require snow to den in the spring. *Jeff Copeland, Forest Service*

Examining the Eastern Edge of Greater Sage-Grouse Habitat

Efforts to aid greater sage-grouse survival, a candidate for Endangered Species Act protection, will be enhanced by a project coordinated at the Rocky Mountain Research Station. Researchers examined nesting ecology in the eastern edge of sage-grouse range, which includes North Dakota and South Dakota. Information about greater sage-grouse and its habitat affect decisions related to grazing and other public-land uses. Researchers found that although only a small amount of eastern habitat exists, it is of good quality and nest initiation rates and bird weights were higher than in other regions. Researchers also found that nests are nearly always beneath sagebrush, and that hatch rates improve when tall grass surrounds the brush. Grass also supports insects that are a critical food source for sage-grouse in the first weeks of life. These research findings will be helpful in grassland management. The Rocky Mountain Research Station Rapid City Lab partnered with the Bureau of Land Management, the North Dakota Game and Fish Department, and South Dakota State University to conduct these studies.

Lead: Rocky Mountain Research Station

▲ A sage-grouse hen on a nest. *Nick Kazcor, Bureau of Land Management*

NetMap Tool Supports Watershed Science and Resource Management

Digital data and geographical information system (GIS) software have increasing value to people planning and managing natural resources for multiple purposes and at scales that reveal ecological processes. Yet technological advances in computer-based analyses cannot be put to the fullest use if they are not widely available, user friendly, or offer consistent coverage over large landscapes. NetMap (http://www.netmaptools.org) is a community-based watershed science system comprising a digital watershed database for the Pacific Northwest, analysis tools, and user forums. The state-of-the-art desktop tool contains about 70 functions and 80 parameters that address watershed attributes and processes such as fluvial geomorphology, fish habitat, erosion, watershed disturbance, road networks, wildfire, hydrology, large woody debris, and change by land use. NetMap integrates with ESRI ArcMap®, a commonly used mapping program, and with nonproprietary GIS software. The community aspect of NetMap allows users to build and upload analysis models and decision-support systems to the "tool library" and access a standardized database of stream and terrain maps. NetMap provides customized watershed analyses at a fraction of the cost of current methods. The Willamette National Forest is using NetMap to prioritize road restoration and removal projects, and the Oregon Department of Forestry is using it to plan timber management.

Lead: Pacific Northwest Research Station

▲ NetMap's decision-support tools facilitate upland and river management, monitoring and research, restoration, and conservation. *Tom Iraci, Forest Service (retired)*

New Genome-Sequencing Method Reveals a Species' Evolutionary History

Organelle genomes from plants, animals, and fungi are used as genetic markers to track maternal diversity, historical migration, and maternally inherited fitness traits in wild populations. These genomes, which range in size from 15,000 to 1 million base pairs, can now be efficiently sequenced in large numbers using multiplexed massively parallel sequencing (MMPS), a technique developed at the Pacific Northwest Research Station. Analyses of complete organelle genomes from conifers (pine chloroplast genomes) and carnivores (fisher mitochondrial genomes) obtained using MMPS show that genetic parameters estimated from complete genomes are not accurately predicted by single organelle genes (a common sampling unit in conservation genetics). This finding highlights the importance of using whole organelle genome sequences when conservation decisions are based on molecular information. The new method for genome sequencing is being used by geneticists at the Pacific Northwest and Rocky Mountain Research Stations to readdress estimates of population distinctiveness for fisher and wolverine in the Pacific Northwest. Results will help guide proposed reintroduction efforts by the U.S. Fish and Wildlife Service. Partners in this project include Linfield College, Oregon State University, Rocky Mountain Research Station, and Santa Clara University.

Lead: Pacific Northwest Research Station

▲ A new method for genome sequencing is being used in wolverine conservation efforts. *John Rohrer, Forest Service*

Wildlife and Fish

DNA Tool Detects White-Nose Syndrome Fungus in Bat Caves

More than a million bats, including rare and endangered species, have succumbed to white-nose syndrome (WNS), a disease first observed in 2007 in Upstate New York. This lethal disease is caused by the fungus *Geomyces destructans*, which continues to spread eastward across the United States. Assessing the distribution of *G. destructans* in environments occupied by hibernating bats is critical for WNS surveillance and management. Northern Research Station scientists, in collaboration with the U.S. Geological Survey, Wildlife Health Laboratory in Madison, WI, are using new molecular identification techniques to characterize the distribution of *G. destructans* in cave sediment samples from bat hibernation sites in the Eastern United States. The fungus was found in cave sediment samples from States where WNS is known to occur, suggesting that the fungus can persist in the environment, but was not found in caves outside the region of known infestations. Closely related fungi, some previously unknown to science, were also found. Bat biologists are using this research to devise strategies to save these animals from extinction. Partners in this project include Symbiology, Inc.

Lead: Northern Research Station

▲ Bats showing symptoms of white-nose syndrome (WNS). *A. Hicks, New York Department of Environmental Conservation*

Inventory and Monitoring

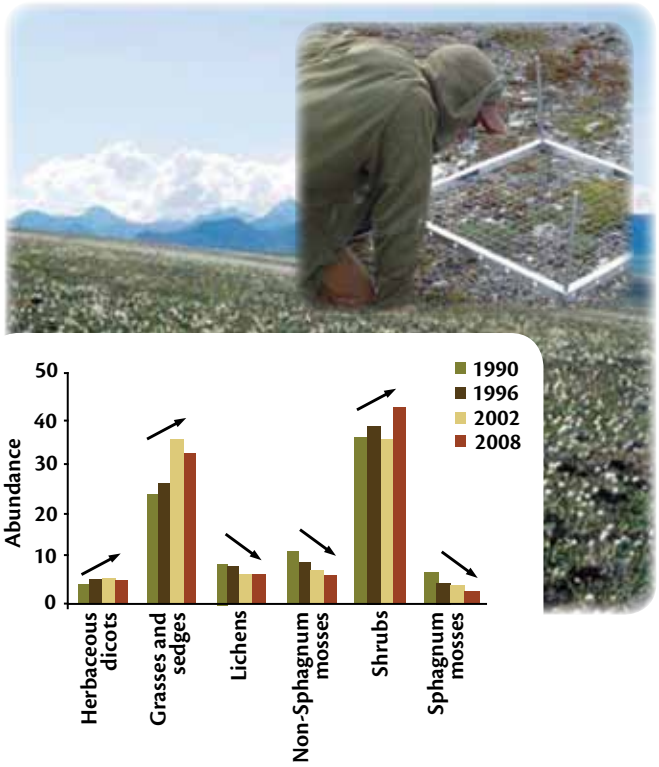
The **Inventory and Monitoring** SPA provides the resource data, analysis, and tools needed to identify current status and trends of forests; management options and impacts; and threats from fire, insects, disease, and other natural processes, thus enhancing the use and value of our Nation's forests and grasslands. Assessing current and potential effects of climate change depends on the monitoring of forest ecosystems at greatest risk to rapid change. Focus areas include the development and use of integrated interdisciplinary science, technologies, and remote sensing to increase the timeliness and spatial resolution of incidence of forest fragmentation, insect outbreaks, diseases, fires, and extreme weather events.

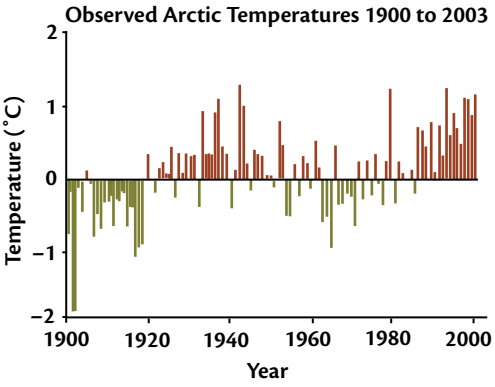
Climate and Vegetation Change in Alaskan Tundra

Studies of tundra vegetation changes in recent decades have predicted an increase in the relative abundance of shrubs in response to climate warming. In contrast, a detailed analysis of a 20-year record of tundra vegetation structure and composition from a set of permanent monitoring plots at Toolik Lake and Imnavait Creek on the Alaskan North Slope indicate a general increase in aboveground biomass, occurring in several growth forms of vascular plants. Specifically, graminoids, herbaceous dicots, and shrubs all increased significantly in abundance (graminoids by 20 percent, herbaceous dicots by 19 percent, and shrubs by 12 percent). The overall proportion of graminoids and shrubs in the community

shifted from 20 and 27 percent, respectively, in 1989 to 25 and 31 percent in 2008. Over the past two decades, relative abundance of vascular vegetation (grasses, herbs, and shrubs) increased by 16 percent while relative abundance of nonvascular vegetation (mosses) decreased by 18 percent. The height, extent, and complexity of the canopy have been increasing over time, with the area covered by multiple layers of vegetation increasing from about 60 to 80 percent. The spread of canopy overstory represents a significant increase in aboveground standing crop as well as a shift in relative carbon allocation from bryophytes to vascular plants. The increase in abundance of vascular vegetation and in canopy height and complexity will likely affect snow redeposition because shrubs capture drifting snow. Shrubs and snowdrift should result in a deeper, looser snowpack that insulates soil surface layers, changing winter biological processes, nutrient allocation, and carbon cycling.

Lead: International Institute of Tropical Forestry





▲ Average annual Arctic air temperatures have risen at almost twice the rate of the rest of the world over the past few decades. The abundance of herbaceous dicots, sedges and grasses, and shrubs has been increasing at our sites since 1989 while the relative cover of *Sphagnum* and other mosses has been decreasing. *Forest Service*

Hurricane-Induced Succession in a Subtropical Wet Forest in Puerto Rico

Quantifying the impacts to forest resources and their recovery from hurricanes and multiple disturbances is essential to managing forests in hurricane-prone areas and understanding the potential impacts of climate change. Research in the Luquillo Experimental Forest in Puerto Rico has documented changes in structure, composition, and nutrients in forests that have been subjected to both hurricanes and droughts. Aboveground biomass was reduced by 50 percent after Hurricane Hugo in 1989, but had recovered within 15 years. However, fewer trees and tree species remained in the forest after 15 years than before the hurricane. Fast-growing pioneer species were mainly responsible for the quick regeneration of forest biomass. These species have different leaf chemistry, which results in different patterns of nutrient cycling after a hurricane. Forest Service scientists also studied the effects of soil or substrate type on post-hurricane regeneration. They found very few differences in forest structure and composition 15 years after a hurricane—differences that are regularly noted in vegetation between sites with different soils were not seen in the

▲ View of the Bisley Experimental Watersheds, Luquillo Experimental Forest, Puerto Rico with *Cecropia schreberiana* (yagrumo) in the valleys and *Dacryodes excelsa* (tabonuco) on the ridges. *Edward Camacho, Forest Service summer student*

study—suggesting that the influence of soil type occurs at a time span much longer than the average return time of hurricanes.the effects of soil or substrate type on post-hurricane regeneration. They found very few differences in forest structure and composition 15 years after a hurricane—differences that are regularly noted in vegetation between sites with different soils were not seen in the study. These few differences suggest that the influence of soil type occurs at a timespan much longer than the average return time of hurricanes.

Lead: International Institute of Tropical Forestry

Maps Illustrate 23 Years of Change on Northwest Forests

By using historical remote-sensing data, researchers developed maps of annual forest change between 1984 and 2007. These maps, with a resolution of 30 meters, of western Oregon, western Washington, and northern California show changes from timber harvests (thinnings to clearcuts), fires (low to high severity), insects and pathogens, and forest increase associated with recovery after disturbance. As a series, the maps contain an unprecedented level of spatial and temporal detail. The ability to illustrate forest change over time was made possible by publicly available satellite data and new algorithms developed by the station and its partners. Land managers and regulatory agencies are using these maps to assess current land management, evaluate status and trends of populations of threatened and endangered species, and develop innovative approaches. For example, the Northwest Forest Plan Effectiveness Monitoring Program is using the maps to assess the effects of forest management and natural disturbance on wildlife habitat for the spotted owl, marbled murrelet, and other old-growth-related species; watershed condition; and socioeconomic factors of forest-product-dependent communities. The National Marine Fisheries Service is using these data to assess effects of forest change on threatened and endangered runs of the coho salmon in Oregon. Partners in this project include the Pacific Northwest Region and Oregon State University.

Lead: Pacific Northwest Research Station

Urban Tree Canopy Assessment Program

Despite millions of dollars spent each year by Federal, State, and local governments on remote sensing datasets, decisionmakers sometimes find that they lack basic information about their community's tree canopy because these datasets have not been converted into practical, readily interpretable information. In the Urban Tree Canopy (UTC) Assessment Program, the Northern Research Station, in partnership with the University of Vermont's Spatial Analysis Laboratory, has developed advanced processing techniques that help fill this information gap. The station has provided new land-cover maps that are 900 times more detailed than existing datasets. These assessments have been completed for more than 30 communities in the United States and Canada. The Association of Natural Resource Educational Professionals has recognized the UTC Assessment Program for its outreach activities. Nobel Laureate Dr. Gerd Binnig also recognized the program for its use of advanced image processing algorithms.

Lead: Northern Research Station

Historic Critchfield Memorial Herbarium Goes Digital

The Forest Service Pacific Southwest Research Station, Institute of Forest Genetics, has released the online version of its historic Critchfield Memorial Herbarium. The Web site includes collection information and a photograph of each specimen. With more than 4,000 specimens, it is believed to be the largest collection of pines in the world. An herbarium—a collection of dried, generally mounted, plant specimens—can be used for a number of purposes, including documenting the taxonomy of a species and providing an educational opportunity for people interested in learning how to identify species. Many college courses include herbarium specimens for species identification. So herbaria are important resources for research and education. The collection information is useful for understanding the current and historical range and diversity of a species. Each specimen is marked with location and date of collection, and many specimens have additional information, including information on the habitat it was found in or other species growing in the area. Having the Critchfield Memorial Herbarium online will facilitate the use of the collection for understanding pine taxonomy, for both education and research. The digital herbarium can be found at http://treesearch.fs.fed.us/psw/topics/forest_genetics/critchfield_herbarium/.

Lead: Pacific Southwest Research Station

▲ An example of one of more than 4,000 species housed at the Critchfield Memorial Herbarium. Note the collection information, accession number, size standard, and color standard that are included to make the images more useful to both researchers and the public. *Forest Service*

The Height of A Forest

The height of a forest and the density of foliage at different heights along the vertical profile of a forest (its "foliage height profile") greatly affect forest ecology. Scientists have known for decades that these aspects of forest three-dimensional structure affect which and how many bird species inhabit a forest canopy. The same is true for many other animals, especially in tropical forests. Forest three-dimensional structure also relates to how forests interact with soils and the atmosphere: how much they cool an area, how much carbon they sequester in biomass, how they help form clouds, and how well they protect watersheds. Until now, mapping of tropical forest height profiles had not been accomplished with satellite imagery of medium spatial resolution, and mapping of forest height with such imagery had limited success. Landsat imagery is the only such imagery that is freely and globally available. Landsat imagery from a single date, however, is generally not sensitive to forest three-dimensional structure. International Institute of Tropical Forestry scientists and collaborators have shown for the first time that tropical dry forest height and height profiles can be mapped by stacking many past Landsat images with a new type of Landsat imagery that will become globally available in 2013. They used images dated from 1985 through 2005 to map forest height and height profiles in southern Eleuthera, The Bahamas, for avian habitat studies. They also used the time series of images to map forest age and history, distinguishing, for example, forests recovering from wildfire from forests that had been cleared for agriculture. Partners in this project include the Remote Sensing Application Center, Southern Research Station, The Nature Conservancy, Colorado State University, and the University of Miami.

Lead: International Institute of Tropical Forestry

Tools for Addressing Bark Beetles

Tree mortality resulting from bark beetle infestation in the Interior West is a risk to human lives, ecosystem health, and rural economic vitality. Rocky Mountain Research Station scientific findings indicate that in lodgepole pine forests, fuel loads and the resulting fire hazard do not change in currently infested stands but

▲ White bark pine trees devastated by the mountain pine beetle. *Ken Gibson, Forest Service (retired)*

Inventory and Monitoring

▲ Adult mountain pine beetle. *Javier Mercado, Forest Service*

will increase substantially when dead trees begin to fall. Station scientists continue to study the progression of the mountain pine beetle epidemic in the Interior West to refine models of forest vulnerability. In addition, station scientists in partnership with regional Forest Health Protection staff determined that partial forest cutting can reduce spruce-beetle-caused tree mortality under typical bark beetle conditions. Implementing partial cutting of forests could help mitigate spruce beetle outbreaks, improving the chances for residual spruce survival and leading to healthier forests for the public to enjoy and utilize.

Lead: Rocky Mountain Research Station

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